NASA TECHNICAL MEMORANDUM

NASA TM X-73481

NASA TM X-73481

(NASA-TM-X-73481) TITAN/CENTAUR D1TTC-3 VIKING B FLIGHT DATA REPORT (NASA) 153 p HC $6.75 CSCL 22D

N76-28259

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TITAN/CENTAUR D-1T TC-3 VIKING B FLIGHT DATA REPORT

by Staff
Lewis Research Center
Cleveland, Ohio

July 1976

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM X-73481		
4. Title and Subtitle TITAN/CENTAUR D-1T TC-3 VIKING B FLIGHT DATA REPORT		5. Report Date
		6. Performing Organization Code
7. Author(s) Staff		8. Performing Organization Report No. E-8863
		10. Work Unit No.
9. Performing Organization Name and Address Lewis Research Center National Aeronautics and Space Administration Cleveland, Ohio 44135		11. Contract or Grant No.
		13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Titan/Centaur TC-3 was launched from the Eastern Test Range, Complex 41, at 02:34 PM EDT on Tuesday, September 9, 1975. This was the third operational flight of the newest NASA unmanned launch vehicle. The spacecraft was the Viking B, the second of two orbiting and landing missions to Mars planned for the 1975 Martian launch opportunity. The objective of the launch phase of the mission, to inject the Viking spacecraft onto the planned transfer orbit to Mars, was successfully accomplished. This report presents a review of the launch vehicle system flight data.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Launch vehicles Flight data Viking B-Mars mission	Unclassified - unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified		

* For sale by the National Technical Information Service, Springfield, Virginia 22161

NASA-C-168 (Rev 10-75)

TC-3 FLIGHT DATA REPORT

VIKING B

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I SUMMARY

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by R. P. Geye

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II INTRODUCTION

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by R. P. Geye

The Viking Mission to Mars is one of NASA's principal planetary efforts of this decade. Two Viking spacecraft were launched from the AFETR Launch Complex 41, Cape Canaveral, Florida, during the 1975 Mars opportunity and will arrive at the planet in mid-1976. Each spacecraft will be placed into orbit around the planet and the landers will subsequently be separated for entry into the Mars atmosphere and a soft landing on the surface of the planet.

The flight plan to accomplish the Viking Mission consists of five major phases of operation: launch, cruise, orbital, entry and landed. The Titan IIIE and Centaur D-1T, together with the Centaur Standard Shroud (CSS), is the launch vehicle developed to meet the Viking launch phase requirements.

Launch Phase of the Viking Mission

The 1975 Mars launch opportunity extended from August 11 through October 13. The launch windows opened as early as about 1400 GMT (10:00 EDT) and closed as late as about 2230 GMT (18:30 EDT). The earliest windows occurred towards the end of the opportunity and the latest windows occurred near the beginning. On any one launch day, the window was about one hour long. The launch azimuth sector used for the mission was 96° from 108° with trajectories yawing from 108° southward to an equivalent azimuth of 115° during the latter part of some daily windows. Parking orbit coast times varied from about 11 minutes to about 28 minutes. Coast time was longest at daily window opening and shortest at closing.

The launch phase of the Viking B mission was accomplished on September 9.

The final profile for Titan Stage 0 phase of flight consisted basically of a short vertical rise with roll to the required flight azimuth, followed by an initial pitch/yaw maneuver and subsequent near zero total angle-of-attack. The required steering, referred to as wind biased steering, was determined on launch day and implemented by the Centaur DCU in an open loop mode. Propellant depletion of the Stage 0 engines activated the Titan Step 0 staging timer (1.5g decreasing axial acceleration) which initiated Titan Stage I engine start, heat shield jettison/Stage I ignition and Titan Step 0 jettison.

During Titan Stages I and II phases of flight, the flight profile was primarily determined by the steering required to achieve a 90 n.mi. parking orbit at the end of the first Centaur burn. The required steering was implemented by combining incremental pitch and yaw rates, derived from the Centaur guidance steering vector, with a rate versus time pitch program that was stored in Titan. Titan Step I jettison/Stage II ignition was initiated by Stage I propellant depletion. The Centaur Standard Shroud was jettisoned 10 seconds

after Stage I shutdown, as sensed by the Centaur DCU. Titan Stage II also burned to propellant depletion which then initiated Titan Step 2 jettison, Centaur chilldown and Centaur Main Engine Start.

The Centaur first burn phase was of relatively short duration and terminated at injection into the 90 n.mi. circular parking orbit. The 90 n.mi. orbit is standard for parking orbit ascent missions. Steering commands were provided by the Centaur DCU based on the guidance steering vector. Main engine cutoff was commanded by guidance when the desired orbit was achieved. Continuous Centaur propellant settling was maintained during the parking orbit coast phase. During most of the coast phase the vehicle was aligned along the inertial velocity vector. Prior to the second burn the vehicle was aligned to the proper attitude for the burn. The second Centaur burn was terminated by guidance when injection conditions satisfied the Viking mission requirements.

Spacecraft separation occurred by Centaur DCU command 220 seconds after Centaur Main Engine Cutoff (MECO-2). Centaur then executed a reorientation and retromaneuver to satisfy planetary quarantine constraints.

Viking Mission Objectives

The goal of the NASA Viking program is to learn more about the planet Mars by direct measurements in its atmosphere and on its surface. Additional scientific data will be acquired from the Orbiter which will circle Mars in a synchronous orbit above the Lander after the latter has descended to the surface. On both the Orbiter and the Lander the primary emphasis will be on biological, chemical and environmental aspects of Mars which are relevant to the existence of life.

The Viking scientific experiments are divided into four groups: Orbiter, entry, Lander and radio. The Lander carries by far the most instruments. It is, in fact, a miniature automated laboratory. The entry experiments involve instruments mounted on a protective shell surrounding the Lander during its high-velocity entry into the Martian atmosphere. The entry experiments will obviously be brief but will give us a unique opportunity to analyze the characteristics of the Martian atmosphere from top to bottom. After the Lander is detached, the Orbiter plays mainly a supporting role, although it may, for selected periods of time, break its radio ties with the Lander and commence independent scientific experiments. The scientific goals and the specific instruments associated with the four groups of experiments are listed in Table 2-1.

TABLE 2-1 - VIKING SCIENTIFIC GOALS AND INSTRUMENTS

Experiment Category	Scientific Goals	Investigations (Instruments)
Orbiter	Perform reconnaissance to verify or search for landing sites Monitor landing sites Obtain data from other areas of the planet Search for future landing sites	Visual imaging (2 television cameras) Atmospheric water mapping (infrared spectrometer) Surface temperature mapping (infrared radiometer)
Entry	Determine composition and structural profile of the ionosphere and atmosphere	Ions and electrons (retarding potential analyzer) Neutral gases (mass spectrometer) Pressure and temperature (pressure, acceleration, and temperature sensors)
Lander	Visually examine the landing site	Visual imaging (2 cameras)
	Search for evidence of life	Direct biology (3 metabolism and growth detectors)
	Search for and study organic compounds and determine atmospheric composition and its variations	Molecular analysis (gas chromatograph mass spectrometer)
	Study inorganic compounds	Mineral analysis (x-ray spectrometer)
	Determine temporal variations of pressure, temperature and wind velocity	Meteorology (pressure, temperature, and wind sensors)
	Determine seismological characteristics	Seismology (3 axis seismometer)
	Determine magnetic properties of surface	Magnetic properties (2 magnet arrays and magnifying mirror)
	Determine physical properties of	Physical properties
Radio	Conduct scientific investigation using the radio and radar systems	Radioscience (Orbiter and Lander radio equipment)

III SPACE VEHICLE DESCRIPTION

III SPACE VEHICLE DESCRIPTION

Viking Spacecraft

by R. P. Geye

The Viking spacecraft consists of two main elements, the orbiter and the lander, shown in the cruise configuration in Figure 3-1. In this configuration the orbiter is structurally attached to the lander through the truss members of the Viking lander capsule adapter.

Orbiter: The orbiter bus is an unequal-sided octagon structure. The necessary electronics and other subsystems are mounted in 16 bays. Louvers are attached to the bays on the sides of the bus to aid in thermal control of subsystem electronics.

The propulsion subsystem, which consists of two propellant tanks, pressurant tank, engine support structure, and a fixed thrust two-axis-gimbaled rocket engine, is attached to the octagonal bus in a modular fashion. Helium pressure is used to feed the storable propellants, nitrogen tetroxide and hy zine, to the rocket engine.

The entire propulsion module is enclosed in a multi-layer insulation bl et for thermal control. Four solar energy controllers are used to regulate the quantity of solar energy reflected into the propulsion module through penetrations in the thermal blanket.

Four solar panels are mounted to the bus by means of outriggers in a fan-like array on the coordinate axes. Each panel is composed of two identical subpanels.

Two batteries are used to augment the solar array when the power demand exceeds its capability, and to serve as a secondary power source during off-sun operations. The power system provides 2.4 KHz single-phase, 400 Hz three phase, regulated dc, and unregulated dc power.

Attitude control jets for pitch, roll and yaw coincident with the coordinator axes are mounted at the outboard edge of each of the solar panels.

Celestial sensors, comprised of a Canopus sensor, cruise sun sensors, sun gate, and a stray light sensor are mounted to the appropriate sides of the bus. Acquisition sun sensors are mounted on the solar panel tips.

Orbiter communication requirements are satisfied by low and high gain antennas and a relay antenna. The low gain antenna is used to provide command coverage in any roll attitude throughout the mission while in a sun-acquired attitude,

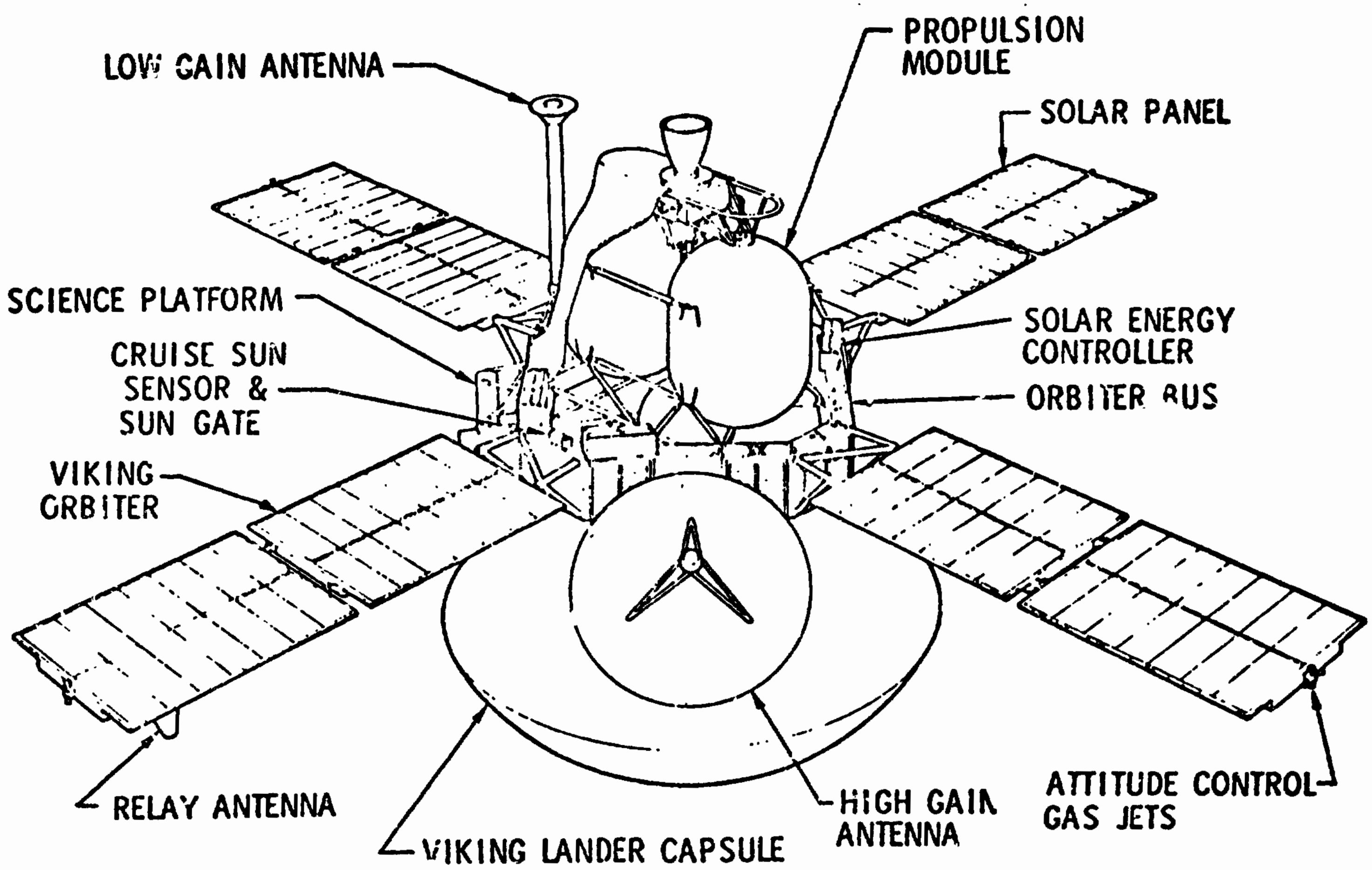

FIGURE 3-1 - VIKING CONFIGURATION IN CRUISE MODE (SUNLIT VIEW)

and also to transmit S-Band signals during the cruise phase. The high gain antenna is used for transmitting and receiving S-Band signals and transmitting X-Band signals during orbital operations and the latter portions of the cruise phase. The relay antenna is used for receiving UHF signals from the lander.

Lander: The basic elements of the lander capsule are the bioshield cap and base, the base cover and parachute system, the aeroshell and the lander.

The bioshield serves to prevent recontamination of the sterilized lander with Earth organisms by completely encapsulating the lander during and after sterilization which is accomplished prior to launch. The cap is jettisoned soon after the spacecraft leaves Earth orbit and the base is jettisoned in Mars orbit after descent capsule separation.

The base cover permits controlled pressure equilization during launch and entry phases by means of a vent system. It is integral with the mortar support structure which contains the parachute system. The mortar is used for parachute deployment. The parachute is a disk gap band configuration used to slow the lander capsule during descent to the Martian surface.

The aeroshell/heatshield is an aluminum-ring-stiffened 140-degree conical shell structure, with a covering of a lightweight ablator material. It provides a suitable shape for entry and protects the lander from aerodynamic beating and other elements of the entry environment.

Figure 3-2 shows the lander in the landed configuration. The lander body is a hexagonally shaped structure which provides a mounting base for the science and other operational subsystems. It is fabricated primarily from aluminum and titanium structural alloys, and is insulated so as to provide environmental protection to the science and supporting subsystems contained therein.

The lander body is supported by three landing leg assemblies. Each leg consists of a main strut assembly and an A-frame assembly to which is attached a footpad. The landing gear stabilizing struts are attached to the bottom corners of the lander body by load limiters. Bonded crushable aluminum honeycomb is used in the main strut for load attenuation at landing.

Three terminal descent engines are attached to the lander sidebeam 120 degrees apart. These engines are the main element of the terminal descent propulsion subsystem which provides roll control, attitude control and a reduction in velocity to the lander after parachute separation. A unique 18-nozzle configuration is used on each engine to minimize soil erosion during lander touchdown.

A reaction control/deorbit propulsion subsystem, utilizing small mono-propellant hydrazine thrusters clustered in four modules mounted near the edge of the aeroshell, provides deorbit thrust and reaction control for lander orientation and rate damping during the lifting entry phase.

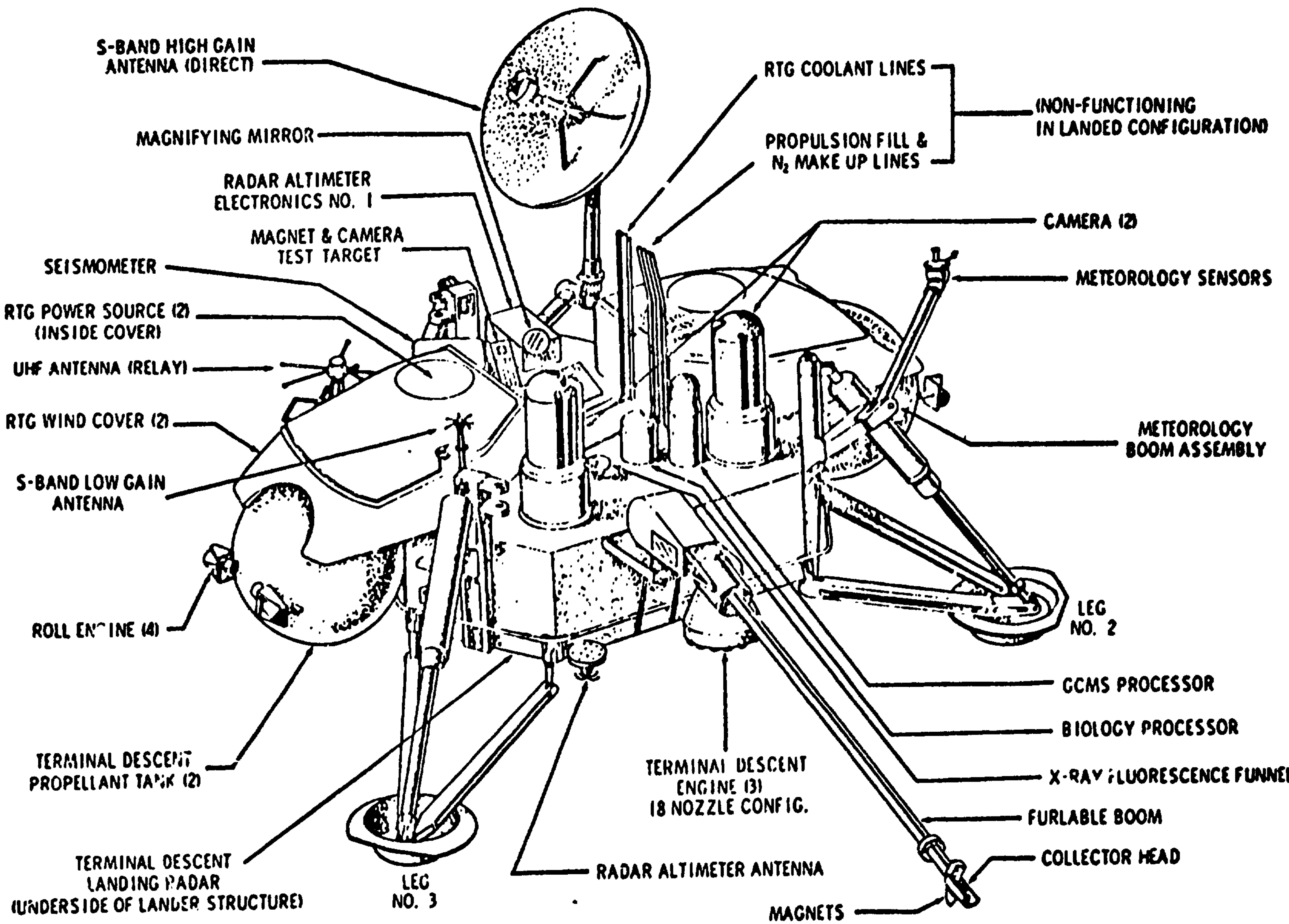

FIGURE 3-2 - VIKING LANDED CONFIGURATION

The lander can transmit data both directly to Earth, using an S-Band communications system, or by way of the orbiter, using a UHF relay system.

The power for the lander is provided by two SNAP 19-style Radioisotope Thermoelectric Generators (RTG's). Lander power requirements in excess of 57 watts are supplied by rechargeable batteries.

The lander has a terminal descent landing radar which is located directly beneath the lander. It consists of four separate CW radars operating at approximately 13 GHz.

The lander has a radar altimeter which is a solid state pulse radar that employs two special design antennas. One antenna is mounted through the aeroshell for high altitude measurements and the other antenna is mounted on the lander for measurements after aeroshell separation.

The lander has a telemetry subsystem which serves to collect and control the flow of scientific and engineering data. It consists of the Data Acquisition and Processor Unit (DAPU), a tape recorder, and a data storage memory.

The Guidance Control and Sequencing Computer (GCSC) is a general purpose digital computer which provides for the flight control system computations and the control and sequencing of the lander components and science instruments. The computer software may be changed or updated through the Earth-to-lander communication system.

Launch Vehicle Configuration

by R. P. Geye

The launch vehicle for Viking B was the four-stage Titan IIIE/Centaur D-1T configuration. This was the third operational flight of this combination of stages.

The overall vehicle configuration is shown in Figure 3-3. The Titan vehicle consists of a two-stage liquid propulsion core vehicle manufactured by the Martin Marietta Corporation and two solid rocket motors (Stage 0) manufactured by United Technology Center. The Titan vehicle integrator is Martin Marietta Corporation. The upper stage is the Centaur D-1T manufactured by General Dynamics Convair Division.

The payload fairing for this configuration is the Centaur Standard Shroud (CSS) manufactured by Lockheed Missiles and Space Company, Inc. Figure 3-4 shows the Centaur/CSS/Viking spacecraft general arrangement.

The following sections of the report give a summary description of the vehicle stage and CSS configurations. Detailed subsystem descriptions can be found in the Flight Data Report for Titan/Centaur TC-1 Proof Flight (NASA TM X-71692). Only configuration differences from TC-1 and/or TC-2 will be addressed in this report.

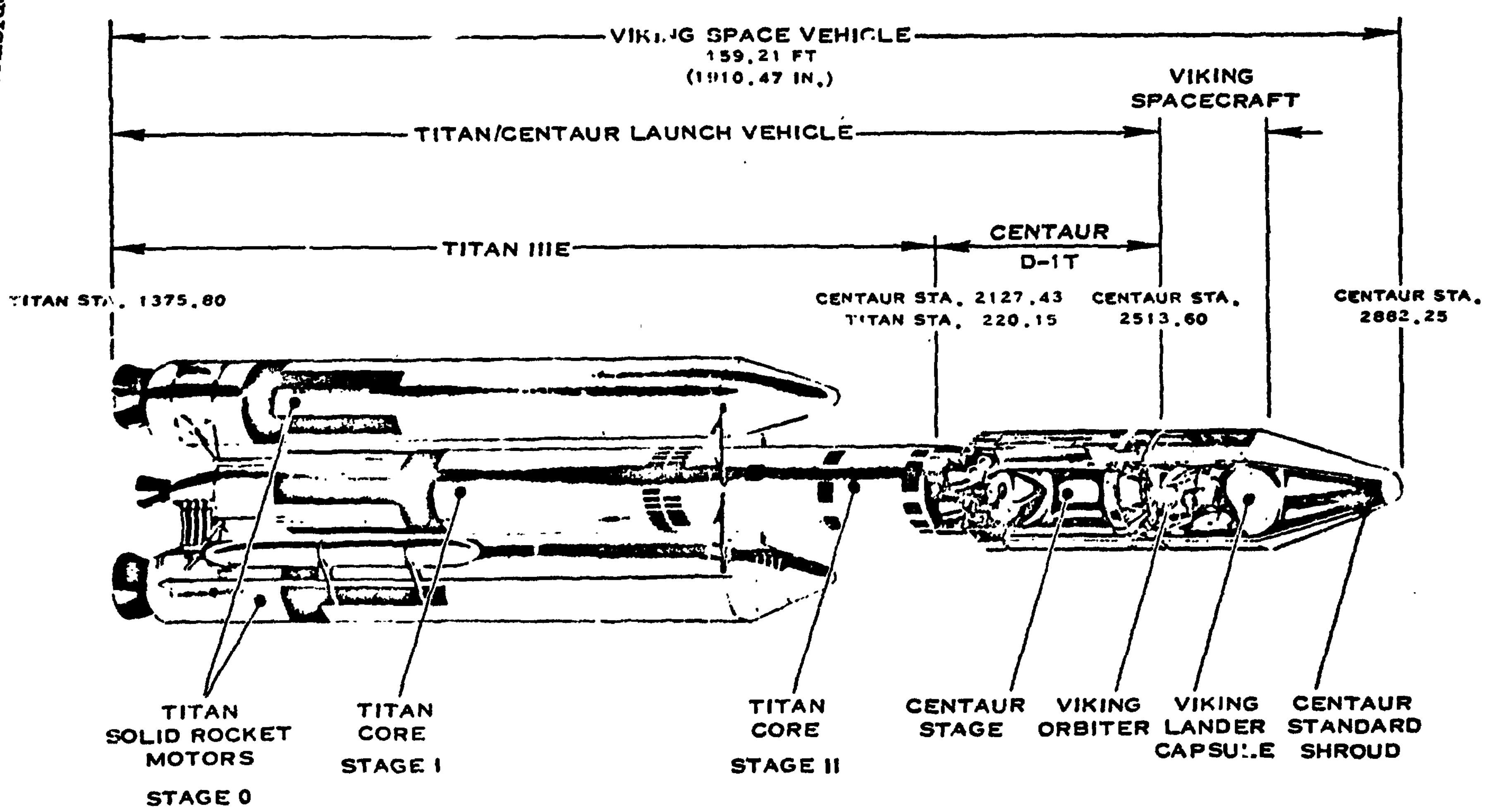

FIGURE 3-3 - OVERALL TC-3, -4 VEHICLE CONFIGURATION

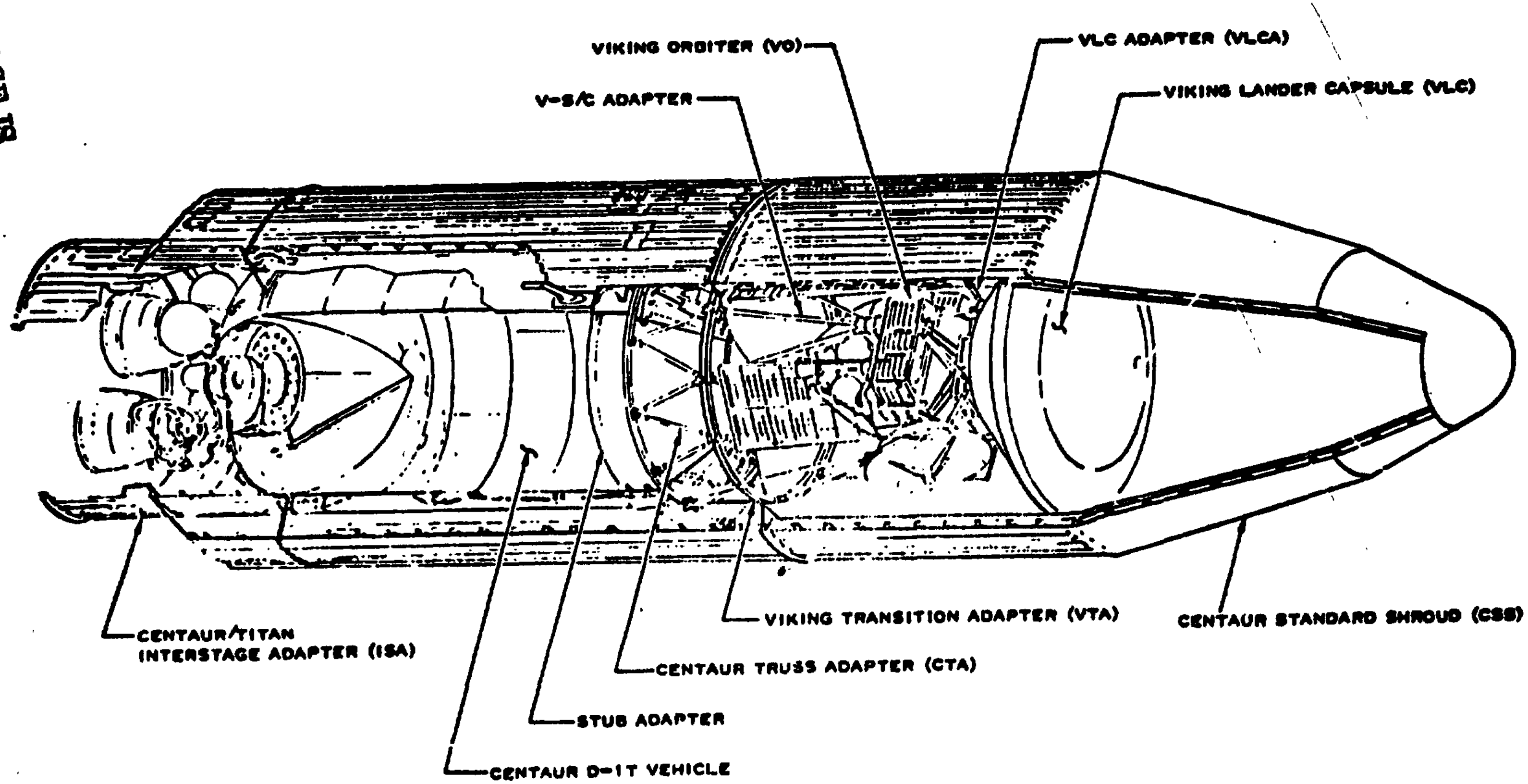

FIGURE 3-4 - CENTAUR VIKING GENERAL ARRANGEMENT

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Titan IIIE

The Titan/Centaur booster, designated Titan IIIE, was developed from the family of Titan III vehicles in use by the Air Force since 1964. The Titan IIIE is a modified version of the Titan IIID. Modifications were made to the Titan to accept steering commands and discretes from the Centaur inertial guidance system instead of a radio guidance system. In addition, a redundant programmer system was added. The Titan IIIE consists of two solid rocket motors designated Stage 0 and the Titan III core vehicle Stages I and II.

The two Solid Rocket Motors (SRM's) provide a thrust of 2.4 million pounds at liftoff. These motors, built by United Technology Center, use propellants which are basically aluminum and ammonium perchlorate in a synthetic rubber binder. Flight control during the Stage 0 phase of flight is provided by a Thrust Vector Control (TVC) system in response to commands from the Titan flight control computer. Nitrogen tetroxide injected into the SRM nozzle through TVC valves deflects the thrust vector to provide control. Pressurized tanks attached to each solid rocket motor supply the thrust vector control fluid. Electrical systems on each SRM provide power for the TVC system.

Titan core Stages I and II are built by the Martin Marietta Corporation. The Stages I and II propellant tanks are constructed of welded aluminum panels and domes while interconnecting skirts use conventional aluminum sheet and stringer construction. The Stage II forward skirt provides the attach point for the Centaur stage and also houses a truss structure supporting most of the Titan IIIE electronics. A thermal barrier was added to isolate the Titan IIIE electronics compartment from the Centaur engine compartment.

Stages I and II are both powered by liquid rocket engines made by the Aerojet Liquid Rocket Company. Propellants for both stages are nitrogen tetroxide and a 50/50 combination of hydrazine and unsymmetrical dimethylhydrazine. The Stage I engine consists of dual thrust chambers and turbopumps producing 520,000 pounds thrust at altitude. Independent gimballing of the two thrust chambers, using a conventional hydraulic system, provides control in pitch, yaw and roll during Stage I flight.

The Stage II engine is a single thrust chamber and turbopump producing 100,000 pounds thrust at altitude. The thrust chamber gimbals for flight control in pitch and yaw and the turbopump exhaust duct rotates to provide roll control during Stage II flight.

To preclude longitudinal oscillations which were encountered during Stage I operation on TC-1 and TC-2, accumulators are installed in the oxidizer feed lines to each of the Stage I thrust chambers on this Titan vehicle. In conjunction with this installation, four pressure measurements are added for ground check of the accumulator bellows pressures.

The Stage I oxidizer autogenous pressurization system consists of two superheaters as flown on TC-1 (only one superheater was flown on TC-2). This pressurization system provides tank ullage pressure during Stage I burn time.

The Titan flight control computer provides pitch, yaw and roll commands to the solid rocket motor's thrust vector control system and the Stages I and II hydraulic actuators. The flight control computer receives attitude signals from the three-axis reference system which contains three displacement gyros.

Vehicle attitude rates in pitch and yaw are provided by the rate gyro system located in Stage I. In addition, the flight control computer generates preprogrammed pitch and yaw signals, provides signal conditioning, filtering and gain changes, and controls the dump of excess thrust vector control fluid. A roll axis control change was added to provide a variable flight azimuth capability for planetary launches. The Centaur computer provides steering programs for Stage 0 wind load relief and guidance steering for Titan Stages I and II.

A flight programmer provides timing for flight control programs, gain changes and other discrete events. A staging timer provides acceleration-dependent discretes for Stage I ignition and timed discretes for other events keyed to staging events. The flight programmer and staging timer, operating in conjunction with a relay package and enable-disable circuits, comprise the electrical sequencing system. On Titan IIIE a second programmer, relay packages and other circuits were added to provide redundancy. Also, capability for transmitting backup commands was added to the Titan systems for staging of the Centaur Standard Shroud and the Centaur.

The standard Titan uses three batteries: one for flight control and sequencing, one for telemetry and instrumentation, and one for ordnance. On Titan IIIE additional separate redundant Range Safety Command system batteries were added to satisfy Range requirements.

The Titan telemetry system is an S-band frequency, pulse code modulation/frequency modulation (PCM/FM) system consisting of one control converter and remote multiplexer units. The PCM format is reprogrammable.

For this Titan vehicle, the following measurements were added beyond the standard Titan IIIE instrumentation: six accelerometers on the Stage I engines, a Stage I oxidizer pump inlet pressure, two narrow band chamber pressure measurements on the two Stage I engines and an orifice and venturi pressure measurement in the Stage I autogenous system.

Many of the modifications to the Titan for Titan/Centaur were made to incorporate redundancy and reliability improvements. In addition to those modifications previously mentioned, a fourth retrorocket was added to Stage II in order to ensure proper Titan/Centaur separation if one motor does not fire. All redundancy modifications to Titan IIIE utilized Titan flight proven components.

Centaur D-1T

The Centaur tank is a pressure-stabilized structure made from stainless steel (0.014 inches thick in cylindrical section). A double-walled, vacuum-insulated intermediate bulkhead separates the liquid oxygen tank from the liquid hydrogen tank.

The entire cylindrical section of the Centaur LH_2 tank is covered by a radiation shield. This shield consists of three separate layers of an aluminized Mylar-dacron net sandwich. The forward tank bulkhead and tank access door are insulated with a multilayer aluminized Mylar. The aft bulkhead is covered with a membrane which is in contact with the tank bulkhead and a rigid radiation shield supported on brackets. The membrane is a layer of dacron-reinforced aluminized Mylar. The radiation shield is made of laminated nylon fabric with aluminized Mylar on its inner surface and white polyvinyl fluoride on its outer surface. This Centaur vehicle has no thermal control shielding on components in the thrust section.

The forward equipment module, an aluminum conical structure, attaches to the tank by a short cylindrical stub adapter.

Two modes of tank pressurization are used. Before propellant tanking, a helium system maintains pressure. With propellants in the tank, pressure is maintained by propellant boiloff. During flight, the airborne helium system provides supplementary pressure when required. This system also provides pressure for the H_2O_2 and engine controls system. This Centaur vehicle has one large helium storage tank.

Primary thrust is provided by two Pratt & Whitney RL10A3-3 engines, which develop 15,000 pounds total thrust each. The engines are fed by hydrogen peroxide fuel boost pumps. This Centaur vehicle has a boost pump cold gas spinup system used for ground checkout of the boost pumps. Engine gimballing is provided by a separate hydraulic system on each engine.

During coast flight, attitude control is provided by four H_2O_2 engine cluster manifold assemblies mounted on the tank aft bulkhead on the peripheral center of each quadrant. Each assembly consists of two 6-pound lateral thrust engines manifolded together.

A propellant utilization system controls the engine mixture ratio to ensure that both propellant tanks will be emptied simultaneously. Quantity measurement probes are mounted within the fuel and oxidizer tanks.

The Centaur D-1T astrionics system's Teledyne Digital Computer Unit (DCU) is an advanced, high speed computer with a 16,384 word random access memory. From the DCU discretes are provided to the Sequence Control Unit (SCU). Engine commands go to the Servo-Inverter Unit (SIU) through six digital-to-analog (D/A) channels.

The Honeywell Inertial Reference Unit (IRU) contains a four-gimbal, all-attitude stable platform. Three gyros stabilize this platform, on which are mounted three pulse-balanced accelerometers. A prism and window allow for optical azimuth alignment. Resolvers on the platform gimbals transform vector components from inertial to vehicle coordinates. A crystal oscillator, which is the primary timing reference, is also contained in the IRU.

The System Electronic Unit (SEU) provides conditioned power and sequencing for the IRU. Communication from the IRU to the DCU is through three analog-to-digital channels (for attitude and rate signals) and three incremental velocity channels. The SEU and IRU combination forms the Inertial Measuring Group (IMG).

The Centaur D-1T system also provides guidance for Titan, with the stabilization function performed by the Titan.

The central controller for the Centaur pulse code modulation PCM telemetry system is housed in the DCU. System capacity is 267,000 bits per second. The central controller services two Teledyne remote-multiplexer units on the Centaur D-1T.

This Centaur vehicle has one FM/FM telepac to transmit wideband spacecraft measurements.

The C-band tracking system provides ground tracking of the vehicle during flight. The airborne transponder returns an amplified radio-frequency signal when it detects a tracking radar's interrogation.

This Centaur vehicle uses a basic d-c power system, with power supplied by one 150 ampere-hour battery and distributed via harnessing. The servo-inverter provides a-c power, 26 and 115 volts, single phase, 400 Hz.

Centaur Standard Shroud

The Centaur Standard Shroud is a jettisonable fairing designed to protect the Centaur vehicle and its payloads for a variety of space missions. The Centaur Standard Shroud, as shown in Figure 3-5, consists of three major segments: a payload section, a tank section and a boattail section. The 14-foot diameter of the shroud was selected to accommodate Viking spacecraft requirements. The separation joints sever the shroud into clamshell halves.

The shroud basic structure is a ring stiffened aluminum and magnesium shell. The cylindrical sections are constructed of two light gage aluminum sheets. The outer sheet is longitudinally corrugated for stiffness. The sheets are joined by spot welding through an epoxy adhesive bond. Sheet splices, ring attachments and field joints employ conventional rivet and bolted construction. The bi-conic nose is a semi-monocoque magnesium-thorium single skin shell. The nose dome is stainless steel. The boattail section accomplishes the transition from the 14-foot shroud diameter to the 10-foot Centaur interstage adapter. The boattail is constructed of a ring stiffened aluminum sheet conical shell having external riveted hat section stiffeners.

The Centaur Standard Shroud modular concept permits installation of the tank section around the Centaur independent of the payload section. The payload section is installed around the spacecraft in a special clean room, after which the encapsulated spacecraft is transported to the launch pad for installation on the Centaur.

The lower section of the shroud provides insulation for the Centaur liquid hydrogen tank during propellant tanking and prelaunch ground hold operations. This section has seals at each end which close off the volume between the Centaur tanks and the shroud. A helium purge is required to prevent formation of ice in this volume.

The shroud is separated from the Titan/Centaur during Titan Stage II flight. Jettison is accomplished when an electrical command from the Centaur initiates the Super-Zip separation system detonation. Redundant dual explosive cords are confined in a flattened steel tube which lies between two notched plates around the circumference of the shroud near the base and up the sides of the shroud to the nose dome. The pressure produced by the explosive cord detonation expands the flattened tubes, breaking the two notched plates and separating the shroud into two halves.

To ensure reliability, two completely redundant electrical and explosive systems are used. If the first system should fail to function, the second is automatically activated as a backup within one-half second.

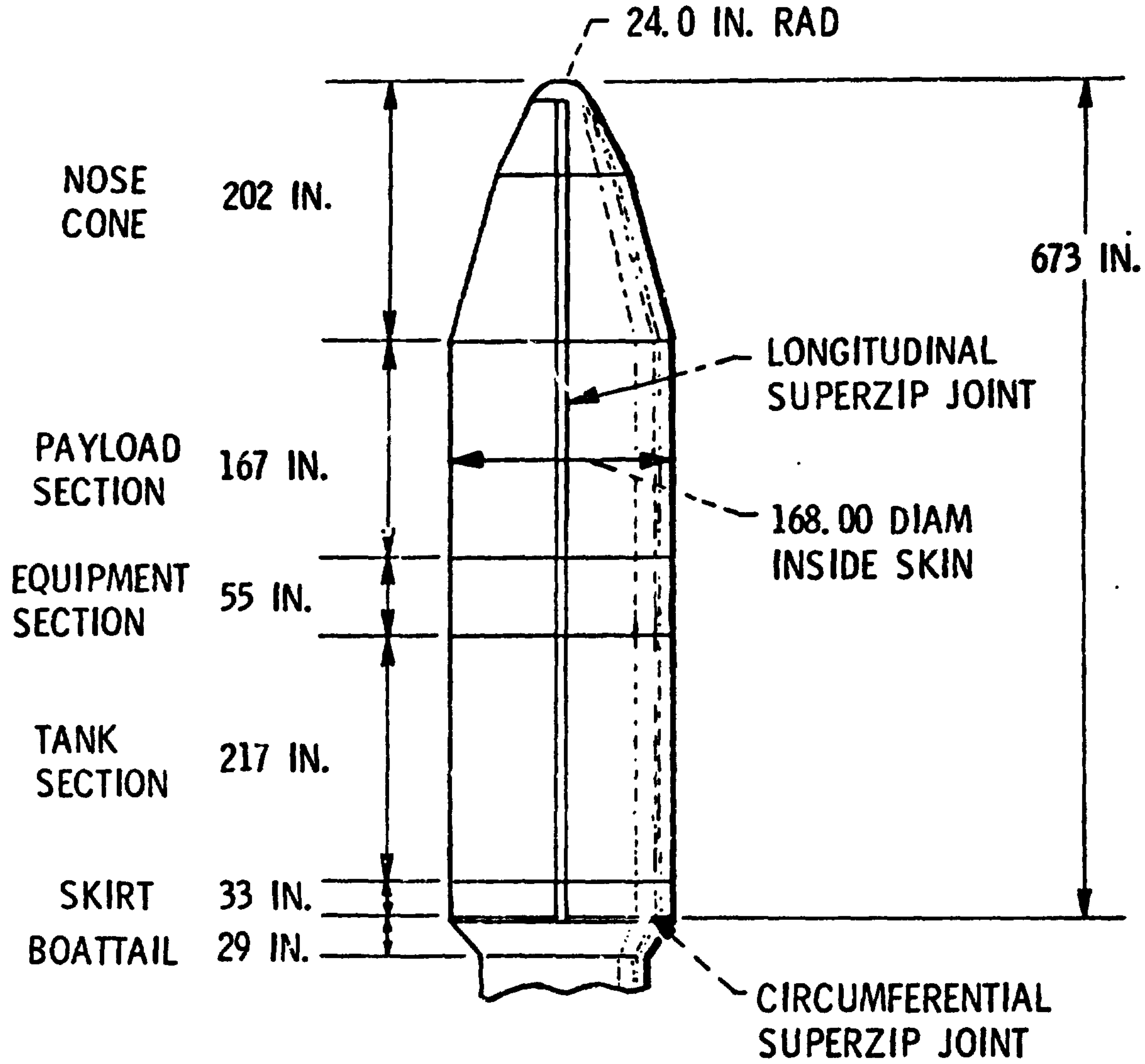


FIGURE 3-5 - CENTAUR STANDARD SHROUD CONFIGURATION

The Titan pyrotechnic battery supplies the electrical power to initiate the Centaur Standard Shroud electric pyrotechnic detonators. Primary and backup jettison discrete signals are sent to the Titan squib firing circuitry by the Centaur Sequence Control Unit (SCU). A tertiary jettison signal, for additional redundancy, is derived from the Titan staging timer.

Four base-mounted, coil-spring thrusters force each of the two severed shroud sections to pivot about hinge points at the base of the shroud. After rotating approximately 60 degrees, each shroud half separates from its hinges and continues to fall back and away from the launch vehicle.

Two additional sets of springs are installed laterally across the Centaur Standard Shroud split lines; one set of two springs in the upper nose cone to assist in overcoming nose dome rubbing friction and one set of two springs at the top of the tank section to provide additional impulse during Centaur/Shroud jettison disconnect breakaway.

.V TRAJECTORY AND PERFORMANCE SUMMARY

IV TRAJECTORY AND PERFORMANCE SUMMARY

by R. P. Kuivinen

The Titan IIIE/Centaur D-1T launch vehicle (TC-3) was successfully launched on September 9, 1975, at 18:38:59.956 GMT (2:38:59.956 PM EDT) placing the Viking . spacecraft onto the correct MARS transfer orbit. Table 4-1 presents the major flight events.

The Titan Solid Rocket Motors (SRM's) were ignited at 18:38:59.956 GMT (2:38:58.956 PM EDT) with liftoff occurring when the thrust of the SRM's exceeded the total vehicle weight. The launch vehicle was rolled from the pad azimuth of 100.2 degrees from true north to the required flight azimuth of 96.508 degrees from true north. The ADDJUST steering programs, P1A5200*TC03 and Y1A5200*TC03, provided the pitch and yaw steering attitude histories for the SRM portion of flight for aerodynamic load relief. These steering programs were designed from wind measurements at launch minus 135 minutes. The trajectory profile through SRM flight was slightly low with Stage I engine ignition occurring at 111.7 seconds into flight and SRM jettison occurring at 122.8 seconds. The velocity at SRM jettison was about 56 ft/sec lower than predicted.

The Stage I portion of flight was 3.3 seconds longer than predicted with Stage I cutoff sensed at 260.9 seconds into flight, with Stage I being jettisoned 0.7 seconds later. The velocity at Stage I cutoff was about 29 ft/sec lower than predicted, but well within the expected dispersion.

The Titan Stage II portion of flight also was 2.2 seconds longer than predicted with the Stage II cutoff sensed at 470.5 seconds. The vehicle at Stage II cutoff was about 67 ft/sec lower in velocity than predicted. During Stage II portion of flight the Centaur Standard Shroud was jettisoned at 271.64 seconds into flight which was 10 seconds after Stage I jettison.

Even though Stages I and II had longer engine firings than predicted, the overall performance of the Titan IIIE vehicle was very good.

The Centaur was separated from the Titan at 473.24 seconds into the flight, with the Centaur first burn main engine start occurring at 483.8 seconds. Centaur Main Engine Cutoff (MECO-1) occurred at 613.4 seconds placing the vehicle into the prescribed parking orbit. Table 4-2 compares selected parking orbit parameters.

After coasting for 18.2 minutes the Centaur second burn occurred to place the Viking 2 spacecraft onto the correct Mars transfer orbit. MES-2 occurred at 1705.7 seconds into flight and MECO-2 occurred at 2007.7 seconds. Table 4-3 compares the Mars transfer orbit parameters.

TABLE 4-1 - VIKING 2, LAUNCH SEPTEMBER 9, 1975, ARRIVE AUGUST 7, 1976

SEQUENCE OF EVENTS FOR TC-3

NO.	FLIGHT EVENTS	TIME (SEC) PREDICTED (1)	ACTUAL
1	SRM IGNITION	T = 0	18:38:59:956 (GMT)
2	SEPARATE FWD BEARING REACTORS	100.0	100.0
3	STAGE I IGNITION	110.69	111.7
4	SRM JETTISON	122.01	123.0
5	STAGE I CUTOFF	257.6	260.9
6	STAGE I JETTISON	258.4	261.6
7	STAGE II IGNITION	258.4	261.6
8	CENTAUR SHROUD JETTISON	269.0	271.6
9	STAGE II CUTOFF	464.0	469.4
10	STAGE II JETTISON	470.0	473.2
11	CENTAUR MES 1	480.5	483.7
12	CENTAUR MECO 1	608.8	613.1
13	CENTAUR MES 2	1698.44	1705.7
14	CENTAUR MECO 2	2004.85	2007.7
15	SPACECRAFT SEPARATION	2224.85	2227.7
16	SOLAR PANEL DEPLOY. COMPLETE	2344.85	(2)
17	BEGIN CENTAUR BLOWDOWN	3079.8	3082.7
18	END CENTAUR BLOWDOWN	3329.8	3332.71

(1) GDC PREFLIGHT ACTUAL LAUNCH TIME TRAJECTORY (PALTT)

(2) EVENT NOT REPORTED

TABLE 4-2 - VIKING 2 (TC-3) PARKING ORBIT

	EXPECTED	ACTUALS CIF	ACTUALS ANTIGUA
EPOCH (SEC)	609.098	6'4.04	612.54
SEMI MAJOR AXIS (KM)	6541.18	6540.89	6542.091
ECCENTRICITY	.000503	.000541	.0003146
INCLINATION (DEG)	29.22958	29.2153	29.2104
PERIGEE (KM)	159.729	159.198	162.976
APOGEE (KM)	166.31	166.273	168.532
C_3 (KM^2/SEC^2)	-60.9372	-60.9398	-60.9287

TABLE 4-3 - VIKING 2 (TC-3) SPACECRAFT INJECTION (MECO-2)

		ACTUALS			
	EXPECTED	CIF	GSFC	VANGUARD	DSS 42
EPOCH (SEC)	2005.35	2018.04	2005.0	2007.3	2007.3
SEMI MAJOR AXIS (KM)	-26469.16	-26441.18	-26463.97	-26412.72	-26496.49
ECCENTRICITY	1.247794	1.248036	1.247759	1.248140	1.24750
INCLINATION (DEG)	29.24139	29.1627	29.155	29.15616	29.0845
PERIGEE (KM)	180.74	180.199	178.52	177.792	181.496
APOGEE(1)	-	-	-	-	-
C_3 (KM^2/SEC^2)	15.059	15.075	15.062	15.0912	15.0436

(1) HYPERBOLIC

Table 4-4 compares the injection orbit parameters mapped at Mars. The tracking parameters presented are based on several days of tracking of the Viking 2 spacecraft by the DSN. A 4.7 meter/sec midcourse correction would have placed the spacecraft on the original launch vehicle target aim point which was biased for planet quarantine purposes. The guidance solution is based on DCU telemetry data and is presented for comparison.

The Centaur completed the launch vehicle mission by performing a deflection maneuver after spacecraft separation to further enhance the Centaur's missing the planet. The orbital parameters for this maneuver are contained in Table 4-5.

TABLE 4-4 - VIKING 2 (TC-3) MARS B-PLANE MAP OF INJECTION PARAMETERS

		ACTUALS	
	TARGETED[1]	GUIDANCE[2]	TRACKING[3]
B. T. (KM)	339730	428084	581972
B. R. (KM)	-163290	-208406	-301786
TCA (MO/DA/YR HR:MIN)	8/8/76	8/8/76	8/9/76
	13:01 GMT	19:48.07 GMT	09:19 GMT
MIDCOURSE REQUIREMENT M/SEC		1.24	4.7

(1) VIKING '75 PROJECT TARGETING SPECIFICATION, MARCH 1, 1975, JPL DOCUMENT: 612-26

(2) GDC COMPUTATION FROM FLIGHT DCU GUIDANCE DATA

(3) JPL COMPUTATION BASED ON SEVERAL DAYS OF DSN TRACKING

TABLE 4-5 - TC-3 CENTAUR DEFLECTION (BLOWDOWN)

	EXPECTED	CIF	VANGUARD
EPOC (SEC)	3329.8	3338.04	3480
SEMI MAJOR AXIS (KM)	-27177.96	-26975.28	-27939.57
ECCENTRICITY	1.240684	1.24267	1.22764
INCLINATION (DEG)	29.241597	29.1602	29.128308
PERIGEE (KM)	163.14	168.03	--
APOGEE (KM) (1)	--	--	--
C_3 (KM^2/SEC^2)	14.666	14.7765	14.2666

(1) HYPERBOLIC

V VEHICLE DYNAMICS

V VEHICLE DYNAMICS

by T. F. Gerus and J. C. Estes

The Titan/Centaur/Viking received dynamic excitation from wind loads, acoustic excitation, and transient forces from engines starting and stopping, and separation events. The following is an evaluation of those excitation sources.

Wind Loads Evaluation: The ADDJUST system was used to design flight steering programs P1A5200*TC03 and Y1A5200*TC03 for the wind profile measured by a Windsonde balloon released at 1614 Z, September 9, 1975. The pitch and yaw components of this wind are shown in Figure 5-1. During prelaunch verification of the flight steering programs, peak response to the 1614 Z wind was calculated to be 79 percent of the weakest structural allowable at 24,931 feet. It should be noted that this response includes a combination of nominal wind response with allowances for such unmeasured and/or non-nominal quantities as gusts, buffeting, trajectory dispersions, and two-hour wind changes.

Titan/Centaur flight wind responses are usually studied using balloon data taken within minutes after the launch. For TC-3, two such required balloon soundings were lost, one due to tracking failure and the other due to ground station error. Therefore, the best available measurement of TC-3 flight winds was from a Windsonde balloon released at 1714 Z, September 9, 1975, 85 minutes before launch. The pitch and yaw components of this wind are shown in Figure 5-2. This balloon reached critical altitude about one hour before launch. Peak calculated response from this sounding was 84 percent of the weakest structural allowable at 23,869 feet. This percentage includes all of the same allowances for extreme conditions described above for the prelaunch design verification. As may be seen in the discussions of measured TVC steering usage (Section VII) and Titan flight controls (Section VII), all of the measured flight wind responses were well below the allowables.

Acoustic Excitation Evaluation: Acoustic levels were measured within the Centaur Standard Shroud near the Centaur equipment module. TC-1 data measured near the equipment module and near the Viking dynamic simulator indicated reasonable comparison so the TC-3 data represent spacecraft acoustic levels. The data was analyzed using standard acoustic analysis techniques by General Dynamics Convair Division and Langley Research Center. Data from both TC-3 and TC-4 is shown for comparison purposes. The data shown on Figures 5-3 and 5-4 indicate reasonable agreement between analyses performed, reasonable repeatability between TC-3 and TC-4, and reasonable margin between measured acoustic levels and the Viking flight acceptance test levels

Transient Loads Evaluation: Transient loads were evaluated early in the Titan/Centaur program for all transients using Viking dynamic model I and repeated later in the program for the more critical conditions using Viking dynamic model VIII. The evaluation of the predicted loads was made by comparing forces predicted on six lander capsule adapter struts with those measured on TC-3 and

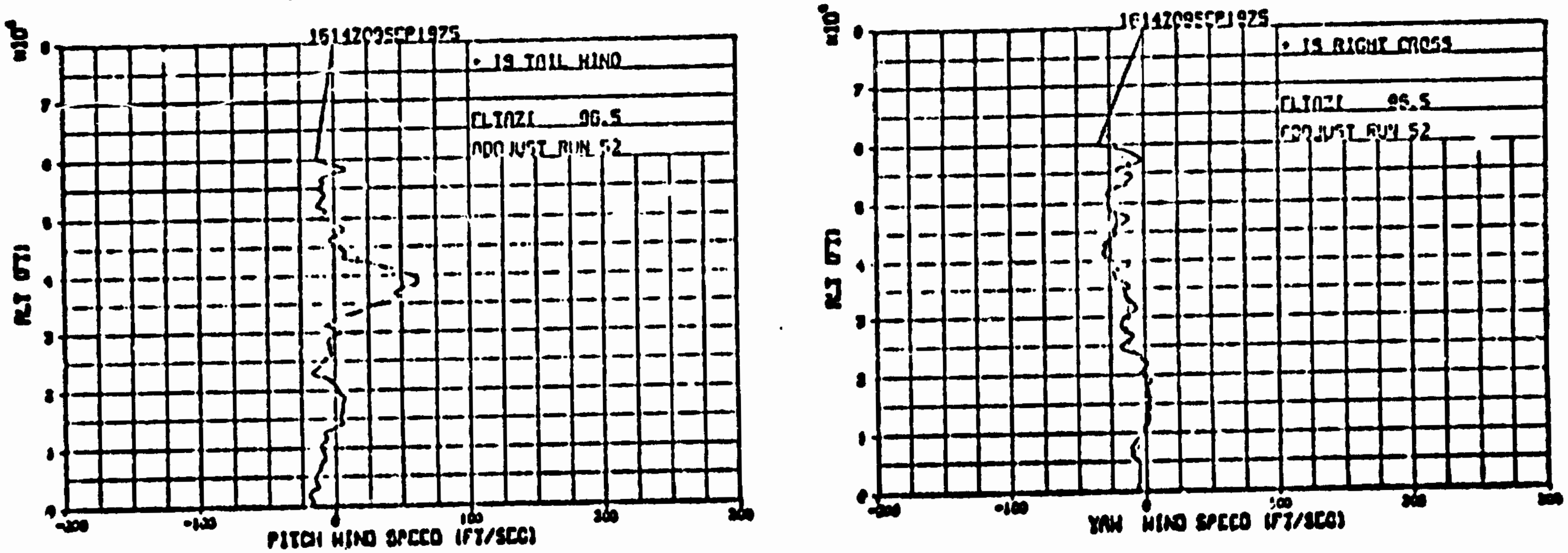


FIGURE 5-1 - WINDSONDE PITCH AND YAW COMPONENTS OF WIND VELOCITY, 1614Z, 9/9/75

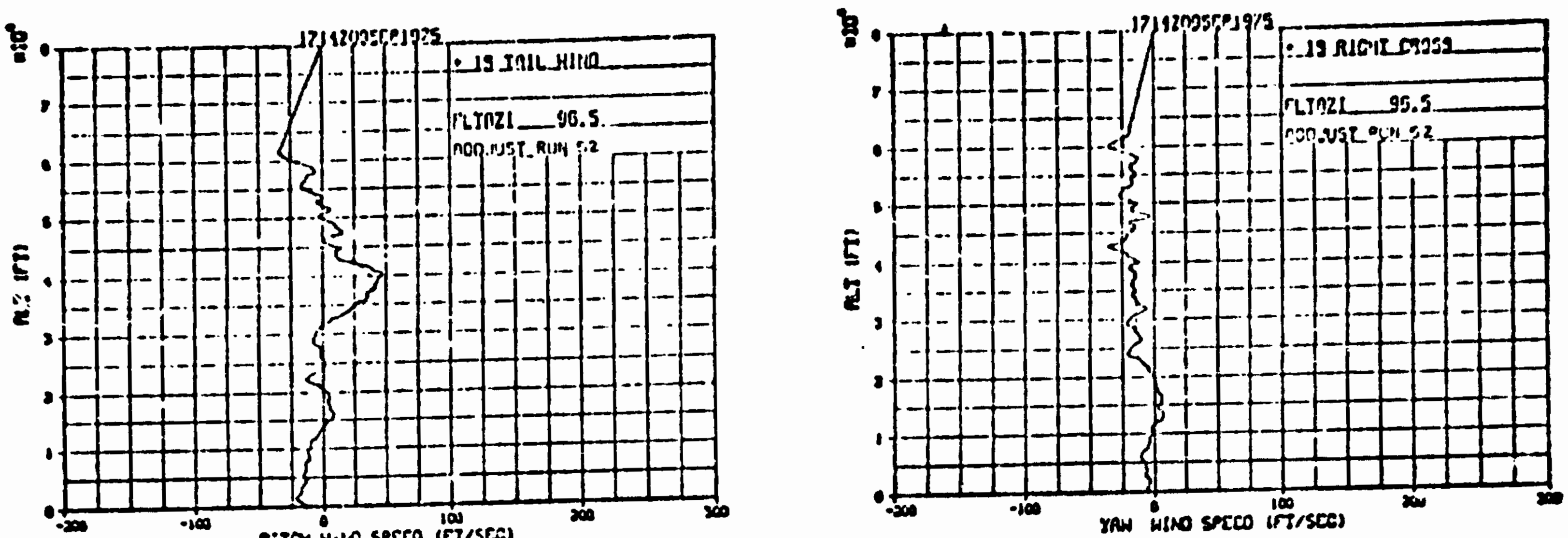
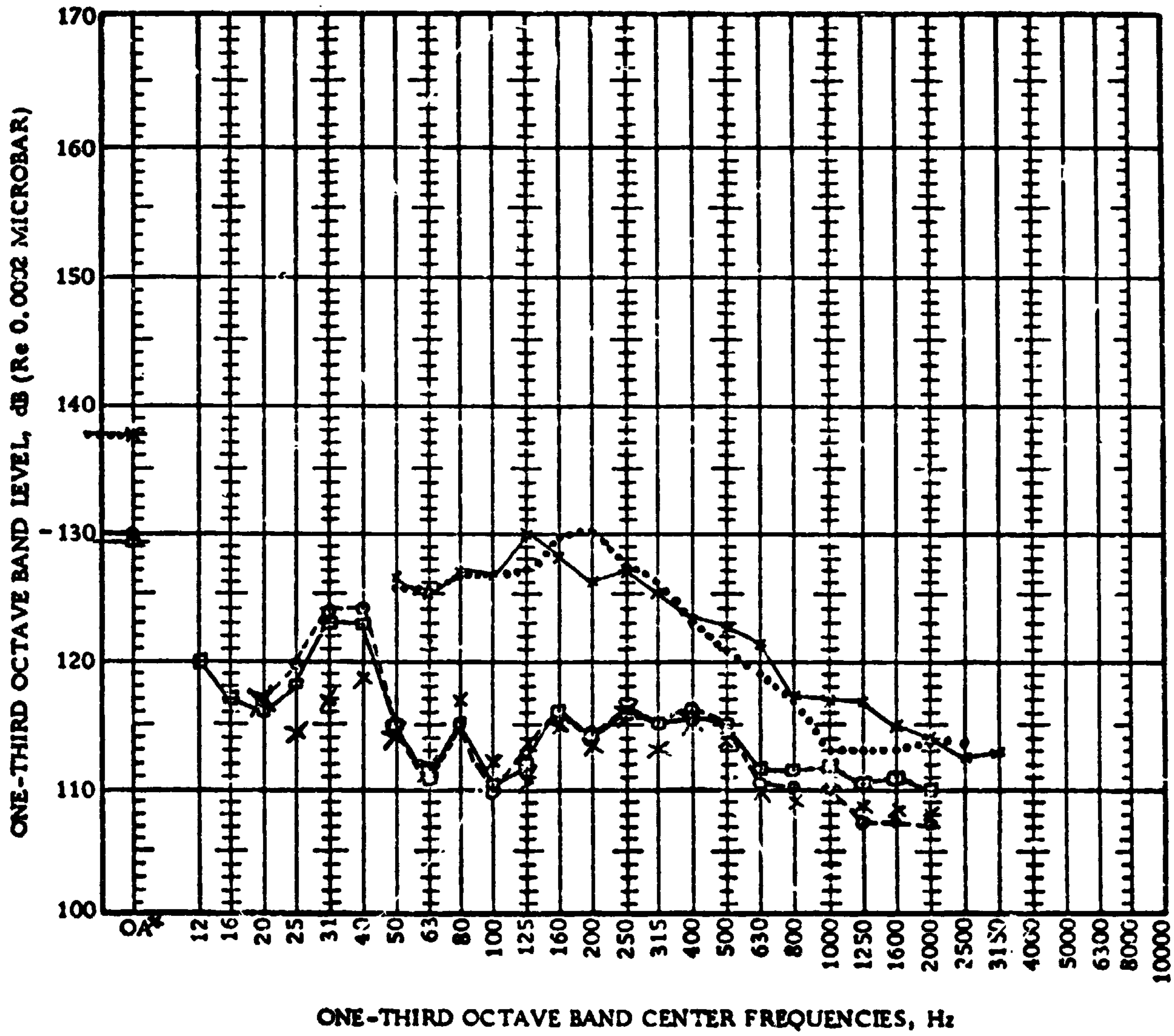


FIGURE 5-2 - WINDSONDE PITCH AND YAW COMPONENTS OF WIND VELOCITY, 1714Z, 9/9/75

FIGURE 5-3 - TC-4/3 ACOUSTICS, LAUNCH

From CA-886-Y

TC-4	LRC Analysis	—□—	129.4 dB OA (20 to 2KHz)
	GDC Analysis	- - - ɵ - - -	130.0 dB OA (20 to 2KHz)
TC-3	GDC Analysis	XX	127.4 dB OA (20 to 2KHz)
	JPL Flight Acceptance Test	....	137.5 dB*
	MMC Flight Acceptance Test	—+—	137.7 dB*

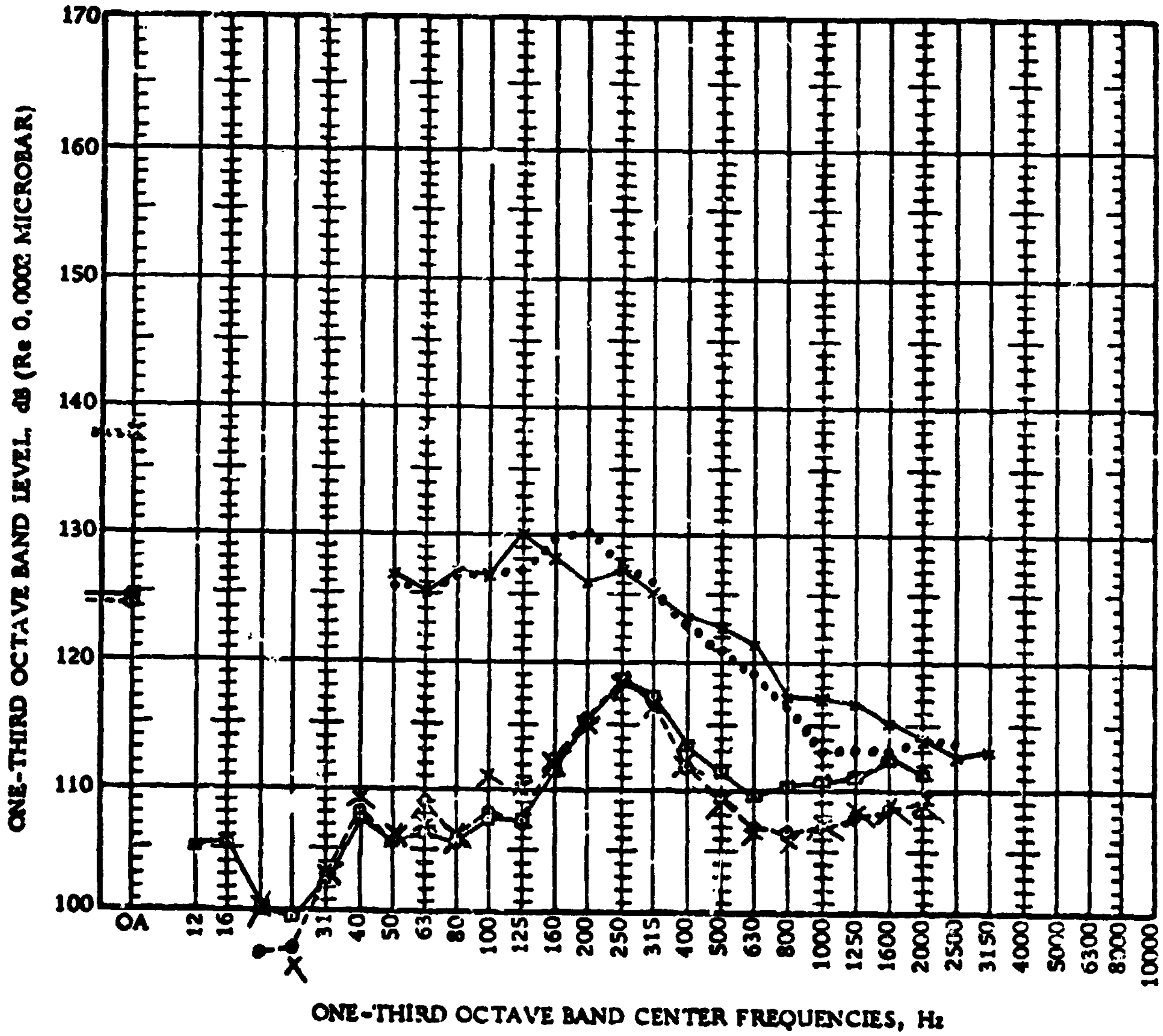


* Over-All (OA) Levels from 20 to 2KHz

FIGURE 5-4 - TC-4/3 ACOUSTICS, TRANSONICS

From CY-886-Y

TC-4	LRC Analysis	——□——	124.9 dB OA*
	GDC Analysis	-----0-----	124.2 dB OA*
TC-3	GDC Analysis	XX	124.5 dB OA*
	JPL Flight Acceptance Test	....	137.5 dB*
	MMC Flight Acceptance Test	——*——	137.7 dB*



*Over-All (OA) Levels from 20 to 2KHz

and TC-4 for comparison purposes. The comparisons are listed on Table 5-1.

Stage 0 ignition is the only condition analyzed using model VIII where the measured loads approached predicted loads and has been determined to be caused by a lack of adequate longitudinal and torsional forcing functions used in the analysis. The other critical loading conditions analyzed adequately compensated for this event, however. Although significant differences between predicted and measured loads are apparent comparing model I analyses, none of those conditions were critical. Differences between predicted and measured loads for these conditions are primarily attributed to dynamic model differences between the flight spacecraft and the model I dynamic model.

The time histories of the Viking Lander Capsule Adapter (VLCA) force data were used in conjunction with the Viking analytical dynamic model in order to evaluate the criticality of all transients to all parts of the spacecraft and launch vehicle. No part of the spacecraft or launch vehicle approached criticality for any transient condition for either TC-3 or TC-4.

TABLE 5-1 - COMPARISON OF VIKING A AND VIKING B MEASURED VICA FORCES TO PRE-FLIGHT ANALYTICAL PREDICTIONS

Member/Meas. No.	Minimum (Compression), lb.			Maximum (Tension), lb.		
	Predicted	Viking A	Viking B	Predicted	Viking A	Viking B
			Stage 0 Ignition (Model VIII)			
750/CY 186S	-2900	-2000	-2300	900	800	100
751/CY 187S	-2700	-1600	-1300	1800	800	1000
752/CY 188S	-2300	-2000	-2200	[illegible]	100	0
753/CY 189S	-2900	-2500	-2800	900	200	1100
754/CY 190S	-2800	-2200	-1500	1900	600	100
755/CY 191S	-2800	-2200	-2300	600	200	200
			Max αq (Model VIII)			
750/CY 186S	-3200	-2000	-1900	1000	-500	-400
751/CY 187S	-2900	-1500	-1200	1800	300	200
752/CY 188S	-3400	-2100	-2100	1200	-400	-300
753/CY 189S	-3600	-1900	-2000	1400	-300	-300
754/CY 190S	-3000	-1500	-1400	2000	200	400
755/CY 191S	-3400	-1900	-2200	1200	-300	-400
			Stage I Ignition (Model I)			
750/CY 186S	-1600	-1400	-1800	0	-800	-800
751/CY 187S	-1200	-1200	-1200	0	0	0
752/CY 188S	-2000	-2000	-1700	0	-600	-600
753/CY 189S	-2100	-1800	-1800	0	-600	-600
754/CY 190S	-1800	-1200	-1200	0	0	-100
755/CY 191S	-2000	-1900	-1900	0	-500	-700
			SRM Jettison (Model I)			
750/CY 186S	-1200	-1500	-1600	0	-400	-300
751/CY 187S	-700	-1000	-1000	0	200	300
752/CY 188S	-1500	-1700	-1700		-500	-200
753/CY 189S	-1200	-1400	-1600	0	-100	0
754/CY 190S	-800	-900	-1100	0	100	200
755/CY 191S	-1400	-1500	-1500	0	-100	-300
			Stage I Burn (Model VIII)			
750/CY 186S	-4900	-2200	-2200	1000	-1600	-1600
751/CY 187S	-2500	-1100	-1000	500	-800	-800
752/CY 188S	-5400	-2200	-2200	1400	-1800	-1600
753/CY 189S	-4500	-2300	-2300	600	-1200	-1500
754/CY 190S	-2900	-1200	-1200	900	-600	-600
755/CY 191S	-4500	-2300	-2400	1300	-1300	-1600

TABLE 5-1 - COMPARISON OF VIKING A AND VIKING B MEASURED VLCA FORCES TO PRE-FLIGHT ANALYTICAL PREDICTIONS

(continued)

Member/Meas. No.	Minimum (Compression), lb.			Maximum (Tension), lb.		
	Predicted	Viking A	Viking B	Predicted	Viking A	Viking B
Stage I Burnout/Stage II Ignition (Model VIII)						
750/CY 186S	-3100	-2600	-2500	2000	300	300
751/CY 187S	-2000	-1300	-1300	1800	100	300
752/CY 188S	-3100	-2700	-2500	2100	300	600
753/CY 189S	-3100	-2500	-2500	1900	400	700
754/CY 190S	-2200	-1400	-1300	2000	300	300
755/CY 191S	-3000	-2700	-2600	2000	600	400
Stage II Burnout (Model IV)						
750/CY 186S	-1500	-1400	-1400	400	0	-100
751/CY 187S	-600	-700	-700	400	-100	0
752/CY 188S	-2000	-1400	-1400	400	-100	0
753/CY 189S	-2400	-1300	-1500	400	0	0
754/CY 190S	-1400	-700	-700	900	100	100
755/CY 191S	-2400	-1400	-1500	900	200	200
Centaur MES II (Model I)						
750/CY 186S	-700	-700	-900	0	0	200
751/CY 187S	-400	-500	-500	100	0	200
752/CY 188S	-800	-900	-900	0	0	200
753/CY 189S	-700	-600	-1000	0	100	200
754/CY 190S	-500	-500	-500	0	0	200
755/CY 191S	-800	-800	-1000	0	100	200
Centaur MECO II (Model IV)						
750/CY 186S	-1400	-1600	-1500	1300	400	500
751/CY 187S	-800	-800	-800	900	400	500
752/CY 188S	-1900	-1600	-1600	1400	600	700
753/CY 189S	-2100	-1500	-1600	1600	800	1000
754/CY 190S	-700	-800	-900	900	300	600
755/CY 191S	-1500	-1700	-1900	900	700	900

Note: Compression = Negative (-), Tension = Positive (+)

All values in the above table have been rounded off to ± 100 lbs.

VI SOFTWARE PERFORMANCE

VI SOFTWARE PERFORMANCE

Airborne

by J. L. Feagan

All available DCU flight telemetry data for the flight of TC-3 was thoroughly reviewed to verify that the flight software performed as designed. The data reviewed included analog plots of the DCU inputs (A/D's), and digital listings of the SCU switch commands and the software internal sequencing. The digital data was also used to verify the proper operation of each module of the flight program as well as the transfer of data between the various modules. The details of the software performance are elaborated upon in the descriptions of the various flight systems; e.g., PU, flight control, guidance, CCVAPS and trajectory.

Computer Controlled Launch Set (CCLS)

by A. L. Gordan

During the TC-3 launch countdown, the performance of the CCLS was normal. No hardware or software problems were encountered. All CCLS countdown procedure tasks were performed within the allowable time marks. This included the receiving and loading of the Centaur DCU with ADDJUST P/Y data coefficients via the ADDJUST transmission links from GDC, San Diego.

VII TITAN IIIE SYSTEMS ANALYSIS

VII TITAN IIIE SYSTEMS ANALYSIS

Mechanical Systems

Airframe Structures

by R. W. York

Summary

The Titan IIIE vehicle airframe configuration remained unchanged from the El Proof Flight configuration. The Titan vehicle maintained structural integrity throughout all phases of booster ascent flight. Data from flight instrumentation agreed well with predicted flight avlues.

Discussion

Response of the vehicle airframe to steady state loads and transient events was nominal with peaks at expected levels.

The ullage pressures within the oxidizer and fuel tanks of both Stage I and Stage II were within prelaunch limits (Table 7-3) and remained sufficient to maintain structural integrity throughout flight. The pressures did not exceed the design limits of the vehicle.

Compartment IIA internal pressure vented as expected and achieved essentially zero psi at approximately 125 seconds after liftoff (Figure 9-9).

SRM separation and Stage I/Stage II separation occurred within predicted three-sigma event times (Table 4-1). Flight data indicates Titan ordnance for these events performed as expected.

Titan Stage 0 Propulsion System

by R. J. Salmi

Summary

The Stage 0 propulsion system for the TC-3 flight was comprised of CSD/UT solid rocket motors numbers 45 and 46. The propulsion performance parameters were within the specification limits or in the expected range from normal flight experience. No system anomalies were detected.

Discussion

Propulsion Performance: The propulsion performance parameters are summarized in Table 7-1. The measured web action times were 104.8 seconds for both SRM's. Corrected from the actual grain temperature of 81.9°F to the nominal temperature of 60°F, the web action time is 107.8 seconds, or 0.9 seconds longer than the specification value of 106.9 seconds, but well within the three-sigma limits of $\pm$ 2.3 seconds. The head-end chamber pressure (Pc) data is presented in Figures 7-1 and 7-2 and the ignition transient phase is shown expanded in Figure 7-3. The chamber pressures were, in general, midway between the specification limits except at ignition and tailoff. At ignition, $P_{c\,(max.)}$ was below the specification limit. The low $P_{c\,(max.)}$ is normal SRM experience and because it is an ignition transient pressure peak it is of no significance to the overall delivered impulse. At tailoff, the pressures were nearer the upper limit as a result of the slightly long burn time. The ignition and tailoff thrust differential were well below the specification limits.

Thrust Vector Control: As listed in Table 7-1, the TVC system oxidizer loads and pressures were near nominal at liftoff, and the TVC tank pressure was well above the minimum value at SRM separation. All electro-mechanical valves (EMV's) in the TVC system operated normally. The maximum steering command was about 1.8 volts which is small relative to the 10-volt range. The TVC injectant usage as determined by CSD/UT is summarized in the following tabulation:

	SRM 45	SRM 46
Nitrogen tetroxide load, lb.	8,417.4	8,41[illegible].9
Total expended, lb.	6,260	6,125
Total dumped, lb.	4,084	4,190
Total TVC steering, lb.	2,176	1,936

TABLE 7-1 - TC-3 SOLID ROCKET MOTOR PERFORMANCE SUMMARY

Parameter	Rocket Motor Specs		SRM 45			SRM 46		
	Nominal or Maximum Allowable	Allowable Deviation	Measured	Corrected	Deviation	Measured	Corrected	Deviation
Nominal Data Condition, °F	60	—	—	60	—	—	60	—
Firing Condition, °F	—	—	81.9	—	—	81.9	—	—
Web Action Time, seconds	106.9	±2.16%	104.8	107.8	+0.84%	104.8	107.8	+0.84%
Action Time, seconds	116.8	±3.43%	115.1	118.3	+1.35%	116.2	119.5	+2.32%
Maximum Forward End Chamber Pressure, psia	791	±3.76%	775	753	-4.80%	780	758	-4.17%
N_2O_4 Loaded, pounds	8424	±42	8418	—	-6	8421	—	-3
Manifold Pressure at Ignition, psia	1041	± 77	1057	—	+ 16	1050	—	+ 9
Manifold Pressure at Separation, psia min	450	—	608	—	—	608	—	—
Thrust Differential During Ignition Transient, lbs max	168,000 @ 0.17 sec	Less than 50,000						
Thrust Differential During Tail-off, lbs max	290,000	Less than 50,000						
Time of Separation, sec	—	123						
Ignition Delay, msec	150 - 300		228			231		

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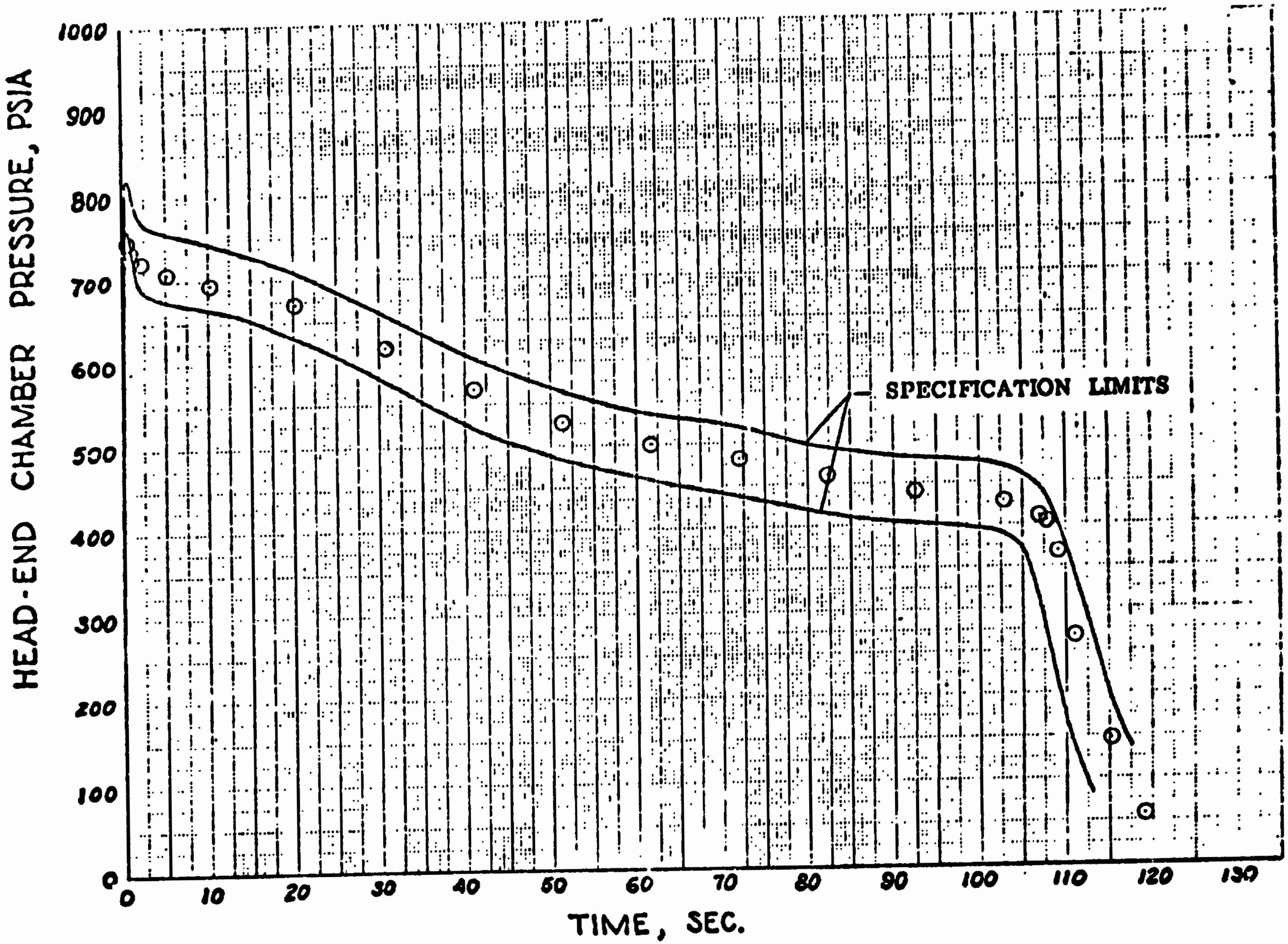


FIGURE 7-1 - COMPARISON OF HEAD-END CHAMBER PRESSURE WITH SPECIFICATION LIMITS SRM No.45, TITAN IIIE - 8. DATA CORRECTED TO 60° F.

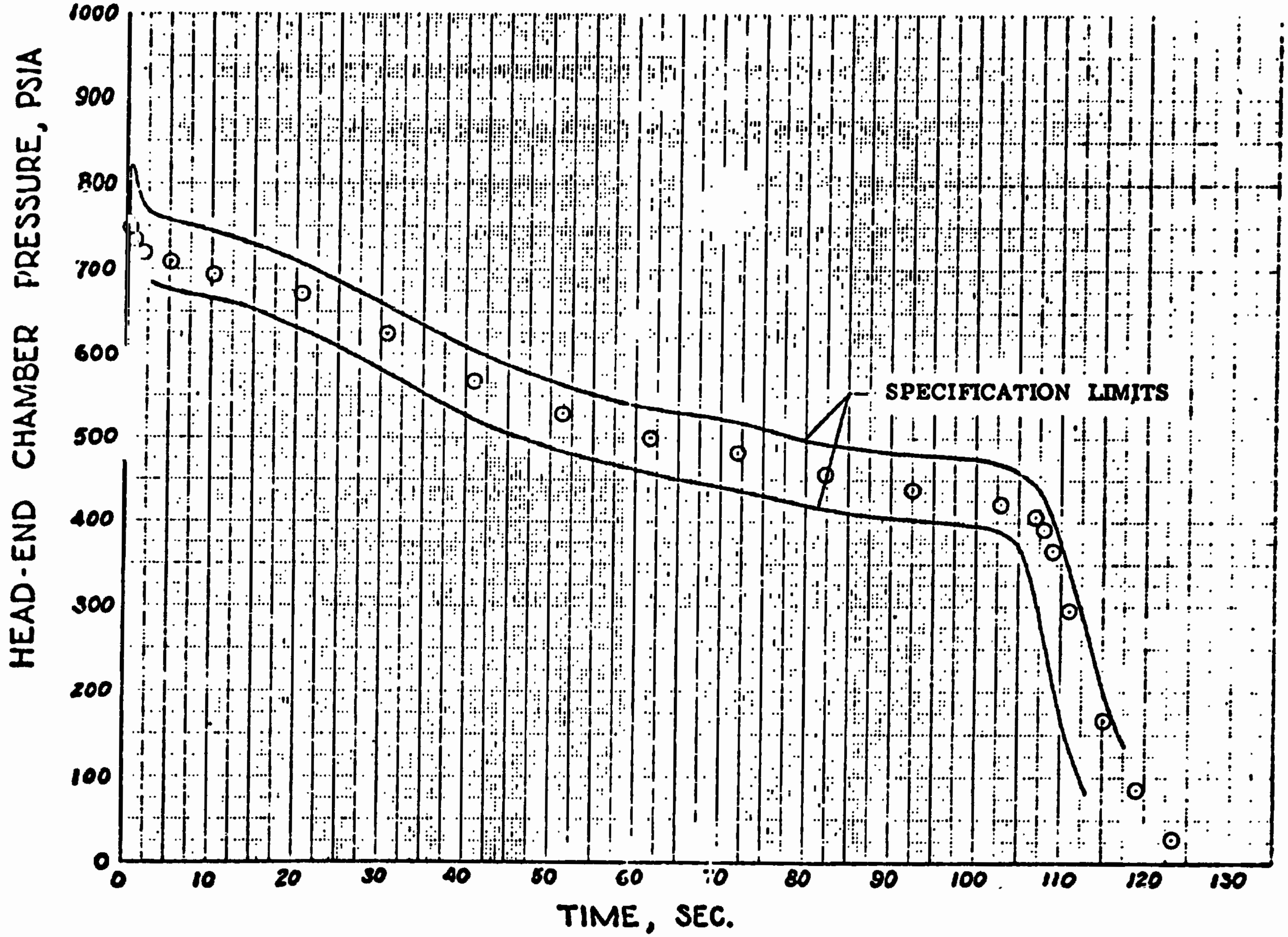


FIGURE 7-2 - COMPARISON OF HEAD-END CHAMBER PRESSURE WITH SPECIFICATION LIMITS. SRM No.46, TITAN IIIE - 8. DATA CORRECTED TO 60° F.

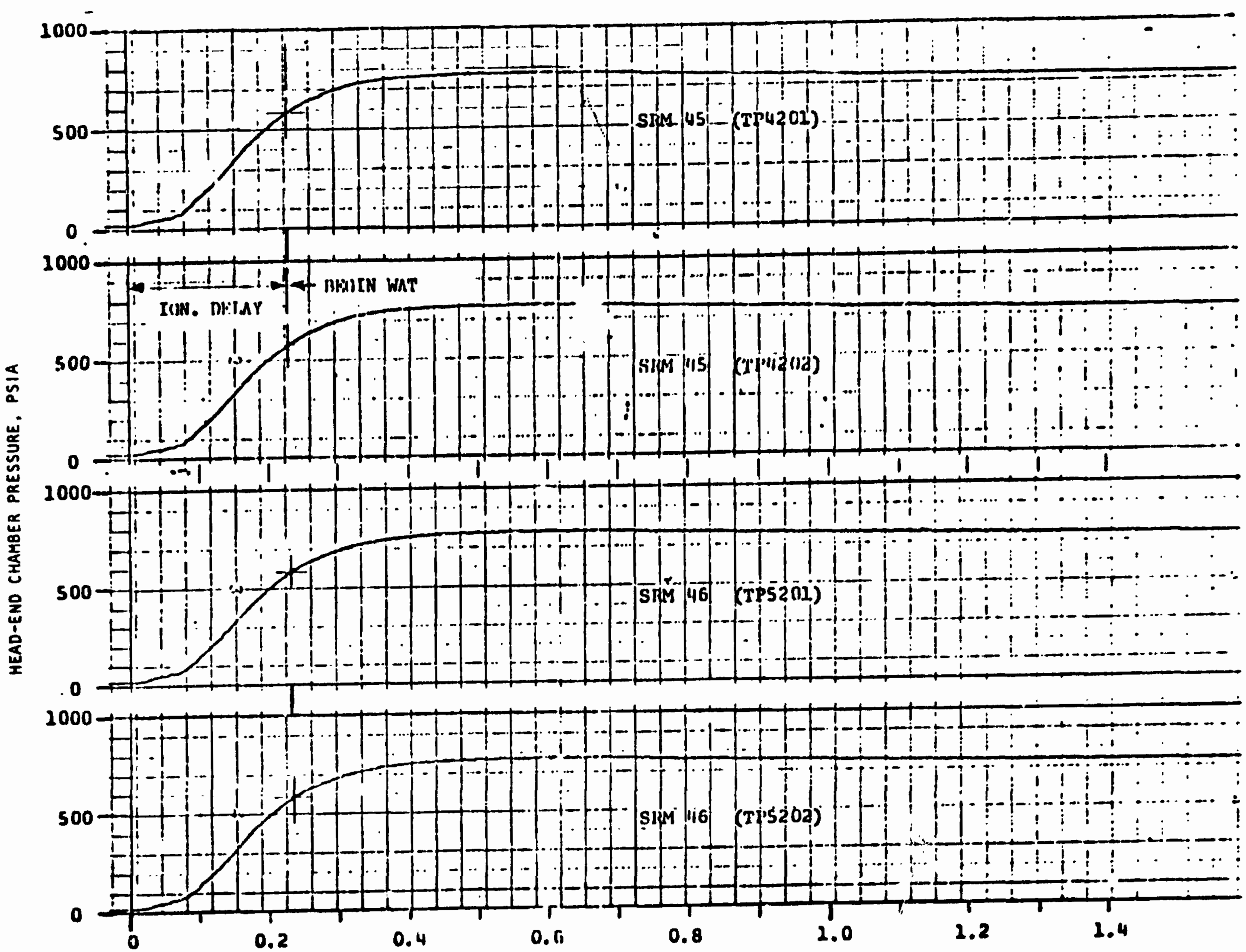


FIGURE 7-3 - SRM HEAD-END CHAMBER PRESSURE IGNITION TRANSIENTS

Titan Stage I and Stage II Propulsion Systems

by R. J. Schroeder

Summary

The Titan Stage I and Stage II propellant loading, prelaunch pressurization, engine performance and autogenous pressurization were all within acceptable limits for the TC-3 flight. Stage I engine shutdown resulted from oxidizer depletion and Stage II shutdown resulted from fuel depletion. Both shutdown transients were normal. Thrust levels were slightly lower than expected but within allowable dispersions. The lower thrust levels resulted in a slightly longer burn time of 2.2 seconds for Stage I and 1.7 seconds for Stage II.

Discussion

Stage I and Stage II Prelaunch Operations: The required propellant loads for Stage I and Stage II were based on an expected in-flight propellant bulk temperature of 80°F for Stage I oxidizer and fuel, 75°F for Stage II oxidizer and 77.5°F for Stage II fuel.

Stage I propellant load was biased to provide a 2.33 sigma probability of having an oxidizer depletion shutdown. This was done to minimize the risk of encountering high Stage II actuator loads during the Stage II engine start transient. Stage I and Stage II propellant tanks were loaded within the allowable limit of $\pm$ 0.3% on the fuel load and $\pm$ 0.4% on the oxidizer load. Comparison of the actual loads with the expected loads is shown in Table 7-2.

Prelaunch tank pressurization was satisfactory. Comparison of the actual oxidizer and fuel tank pressures with the allowable prelaunch limits at T-30 seconds is shown in Table 7-3. All four propellant tank pressures were near the middle of the launch limits. AT T-17.5 seconds the propellant prevalves were commanded open and all six valves were fully open within 6.9-7.2 seconds.

Stage I Propulsion System: The Stage I propulsion system was modified from TC-1 and TC-2 by the addition of oxidizer POGO accumulators on the feed lines to each of the two oxidizer pumps. This change was incorporated to eliminate the longitudinal oscillations encountered on TC-1 and TC-2 during Stage I operation.

Flight performance of the Titan Stage I engine was satisfactory. Engine start signal (87FS1) occurred at T + 110.9 seconds when the accelerometer in the Titan flight programmer sensed a reduction in acceleration to 1.5 g's during the tail-off period of the Stage 0 solid rocket motors.

Engine start transients on both subassemblies were normal indicating satisfactory jettison of the nozzle exit closures.

TABLE 7-2 - TITAN LOADED PROPELLANT WEIGHTS STAGE I AND STAGE II - TC-3

	Expected (Lbs.)	Actual (Lbs.)
Stage I		
Oxidizer	166,611	166,742
Fuel	89,548	89,607
Stage II		
Oxidizer	43,010	43,044
Fuel	23,981	23,995

TABLE 7-3 - TITAN PROPELLANT TANK PRELAUNCH PRESSURIZATION, STAGE I AND STAGE II - TC-3

	Prelaunch Limits (psia)		Value at T-30 Sec (psia)
	Lower	Upper	
Stage I			
Oxidizer Tank	33.6	45.0	40.4
Fuel Tank	24.0	32.0	30.4
Stage II			
Oxidizer Tank	45.0	57.0	49.2
Fuel Tank	50.0	56.0	53.2

Steady-state performance of the Stage I engine was satisfactory. Average engine thrust was 1.01% lower than expected; average specific impulse was .05 seconds higher than expected; and average mixture ratio was 1.22 % lower than expected. These performance parameters were within the allowable three-sigma dispersions of ± 3.27% on thrust, ± 2.3 seconds on specific impulse and ± 2.17% on mixture ratio. Performance of the autogenous pressurization system during engine operation was satisfactory. Comparison of the average expected steady-state performance values for the Stage I engine with the actual steady-state values is shown in Table 7-4.

Stage I engine shutdown occurred at T + 260.9 seconds when the thrust chamber pressure switches sensed a reduction in chamber pressure and issued the engine shutdown signal (87FS2). Engine shutdown was the result of oxidizer depletion as planned. The shutdown transient was normal for an oxidizer depletion mode. Propellant outage was 400 pounds of fuel which was less than the expected mean outage of 1,486 pounds of fuel. This was the result of the shift in mixture ratio. Stage I engine operating time (FS1 to FS2) was 2.2 seconds longer than expected due to the lower than expected propellant flow rates.

Stage II Propulsion System: Flight performance of the Titan Stage II engine was satisfactory. Engine start signal (91FS1) occurred at T + 260.9 seconds (simultaneous with Stage I engine shutdown signal, 87FS2). The Stage II engine start transient was normal. Stage I separation occurred 1.8 seconds after 91FS1.

Engine steady-state performance was satisfactory. Average engine thrust was 1.14% lower than expected, average specific impulse was 1.90 seconds lower than expected and average engine mixture ratio was 0.60% lower than expected. The allowable three-sigma dispersions about the expected values were ± 3.80% on thrust, ± 3.5 seconds on specific impulse and ± 2.66% on mixture ratio. Performance of the autogenous pressurization system during engine operation was satisfactory. Comparison of the average expected steady-state performance values for the Stage II engine with the actual steady-state values is shown in Table 7-5.

Stage II engine shutdown (91FS2) occurred at T + 469.4 seconds when the sensed vehicle acceleration dropped to 1.0 g's. Engine shutdown was the result of fuel depletion. The shutdown transient was normal for a fuel depletion mode. Propellant outage was only 28 pounds of oxidizer compared to an expected mean outage of 110 pounds of propellant. Engine operating time (FS1 to FS2) was 1.7 seconds longer than expected due to the lower than expected propellant flow rates.

Stage II/Centaur separation occurred 3.8 seconds after 91FS2 when the vehicle acceleration level reached 0.1 g. Satisfactory operation of the Stage II retrorocket motors was achieved.

TABLE 7-4 - TITAN STAGE I ENGINE STEADY-STATE PERFORMANCE - TC-3

Parameter	Units	Average Steady-State Flight Values	
		Expected (2)	Actual
Thrust, total	lbf.	520,485	515,223
Specific impulse	sec.	302.07	302.12
Mixture ratio, O/F	units	1.8986	1.8754
Overboard propellant flow rate, total (1)	lbm/sec.	1723.06	1705.37
Oxidizer flow rate, total	lbm/sec.	1131.23	1114.87
Fuel flow rate, total	lbm/sec.	595.81	594.48
Propellant outage	lbm	1486 mean 3375 max.	400 (fuel)
Oxidizer temperature	^{o}F	80	84.1
Fuel temperature	^{o}F	80	[illegible].2
Oxidizer tank pressure	psi	34.7	34.1
Fuel tank pressure	psi	26.5	26.1
FS_1 to FS_2	sec.	147.8	150.0

NOTES: (1) Excludes autogenous pressurant flow.

(2) Expected values are those used in the final preflight targeted trajectory.

TABLE 7-5 - TITAN STAGE II ENGINE STEADY-STATE PERFORMANCE - TC-3

Parameter	Units	Average Steady-State Flight Values Expected (3)	Actual
Thrust, total	lbf.	102,946	101,770
Specific impulse (1)	sec.	317.00	315.10
Mixture ratio, O/F	units	1.8016	1.7871
Overboard propellant flowrate, total (2)	lbm/sec.	322.05	319.90
Oxidizer flowrate, total	lbm/sec.	207.92	205.94
Fuel flowrate, total	lbm/sec.	115.41	115.24
Propellant outage	lbm	110 mean 533 max.	28 (oxidizer)
Oxidizer temperature	°F	75	76.2
Fuel temperature	°F	77.5	83.9
Oxidizer tank pressure	psi	53.0	55.4
Fuel tank pressure	psi	56.4	58.4
FS_1 to FS_2	sec.	206.7	208.4

NOTES: (1) Excludes roll nozzle thrust.

(2) Excludes autogenous pressurant flow.

(3) Expected values are those used in the final preflight targeted trajectory.

Titan Hydraulic System

by T. W. Godwin

Summary

Performance of the hydraulic systems on Stage I and Stage II was normal during preflight checkout and the boost phases of the TC-3 flight. Stage II actuator loads were considerably below previous maximums. There were no anomalies.

Discussion

Performance data for the Titan hydraulic systems are summarized in Table 7-6a. Except for Stage II pressure, all system parameters were nominal and within specification limits. The electric motor pump in each stage supplied normal hydraulic pressure for the flight control system tests performed during countdown. Hydraulic reservoir levels were within limits throughout the countdown and flight. Stage I hydraulic pressure was normal. Stage II pressure was 65 psi below specification. Since this is within the three-sigma error limit for th instrumentation and telemetry (± 100 psi), it may be a measurement error rather than a below specification hydraulic pressure.

Stage I actuator peak loads at engine start were nominal and well within the family of Titan data experience. Stage II peak actuator loads at engine start were comparable to those of TC-4, in that they were only about one-third of the maximum loads experienced on previous TIIIE vehicles (TC-1 and TC-2). Table 7-6b shows the maximum actuator loads encountered during the engine start transients. Also shown for comparison are the TC-1/-2/-4 maximums and the maximums for all Titan vehicles.

TABLE 7-6 - TITAN HYDRAULICS SYSTEM - TC-3

a) System Pressure and Reservoir Levels

Parameters		Units	Expected Values	Flight Results Stage I	Flight Results Stage II
Hydraulic Supply Pressure	Maximum at pump start	psig	4500 (1)	3370	3600
	Average steady state	psig	2900 - 3000	2970	2835(2)
Reservoir Levels	Prior to pump start	%	47 - 62	50	51
	At maximum start pressure	%	22 - 47	37	37
	Average steady state	%	22 - 47	38.5	41
	Shutdown minus 5 seconds	%	22 - 47	40	43

(1) Proof Pressure Limit
(2) Out of Tolerance - See Text

b) Actuator Loads During Engine Start Transients

	Stage I Actuator Loads, Pounds				Stage II Actuator Loads	
S/A	Subassembly #2		Subassembly #1		Subassembly #3	
Actuator Position	Pitch 1-1	Yaw-Roll 2-1	Yaw-Roll 3-1	Pitch 4-1	Pitch 1-2	Yaw-Roll 2-2
TC-3 (E-3)	+10,600 - 6,640	+ 8,700 - 4,150	+ 7,200 - 5,120	+12,800 -18,780	+ 2,750 - 690	+ 4,460 - 1,020
TC-1/-2/-4 Max.	+ 8,300 - 9,270	+12,070 - 5,530	+12,450 - 4,980	9,540 -16,000	+ 9,700 - 890	+ 9,750 - 7,900
Titan Family* (Maximums)	+14,100 -15,400	+12,500 - 8,151	+15,400 - 6,920	+13,030 -18,782	+14,400 - 8,750	+ 9,750 -11,184

* TIII C/D/E - only for Stage I
\+ Indicates Compression Load
\- Indicates Tension Load

Flight Controls and Sequencing System

by E. S. Jeris

Summary

The flight control system maintained vehicle stability throughout powered flight. All open loop pitch rates and preprogrammed events were issued as planned. No system or component anomalies occurred. Dump programming of TVC injectant fluid was satisfactory.

During Stage I flight, a low level roll limit cycle oscillation was observed. The oscillation occurred for approximately 20 seconds after SRM jettison with a peak rate of .48°/sec. and a peak displacement of .36°. The oscillations reoccurred for approximately 7 seconds prior to Stage I shutdown with approximately one-half the peak displacement and rate. Previous TIIIE vehicles did not exhibit this oscillation, but it has occurred on other TIIIE vehicles. Cause is probably higher than usual (but not out of spec) actuator deadband and/or non-linearity. There was no adverse affect on vehicle performance.

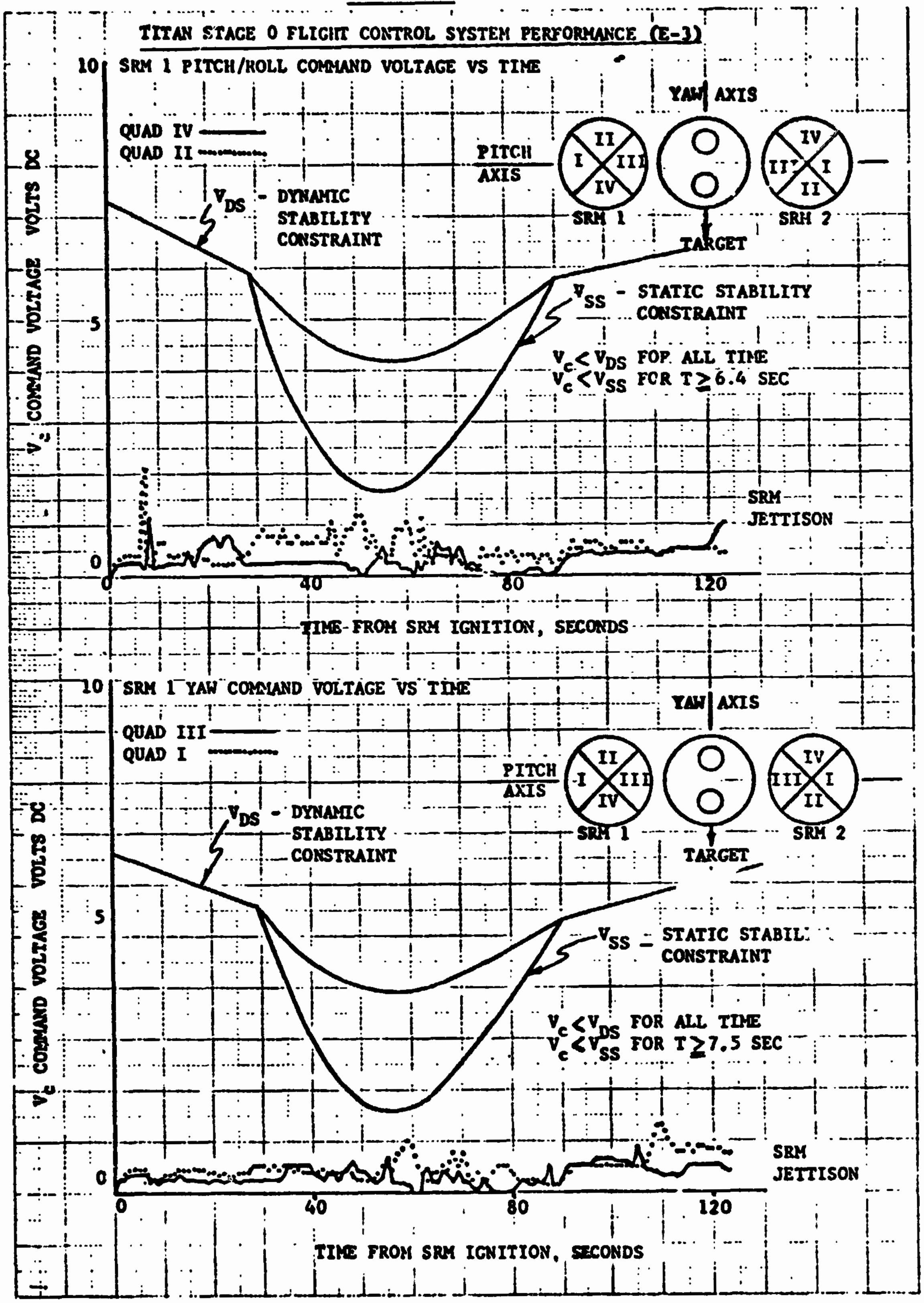
Discussion

Command voltage to each SRM quadrant and the dynamic and static stability limits are shown in Figures 7-4 and 7-5. The stability limits represent the TIIIE-3 side force constraint in terms of TVC system quadrant voltage. This constraint is used in conjunction with launch day wind synthetic vehicle simulations as a go/no-go criterion with respect to vehicle stability and control authority. Simulation responses satisfying the constraint assures a three-sigma probability of acceptable control authority and vehicle stability. Maximum command during Stage 0 flight was 2.08 volts which is 20.8% of the control system capability and 29.7% of the dynamic stability limit. The peak command occurred at T + 7 seconds and was used for the roll to azimuth maneuver commanded by Centaur.

For Stage I and II, the control system limit is the maximum gimbal angle associated with the actuator stop. During Stage I flight, the peak gimbal angle required for control was .83° which is 19% of the maximum gimbal angle. The peak angle was used at guidance enable (T + 149 seconds) when Centaur sent a 2° pitch up command. During Stage II, 8.5° or 25% of peak gimbal angle was the maximum gimbal angle required at CSS jettison.

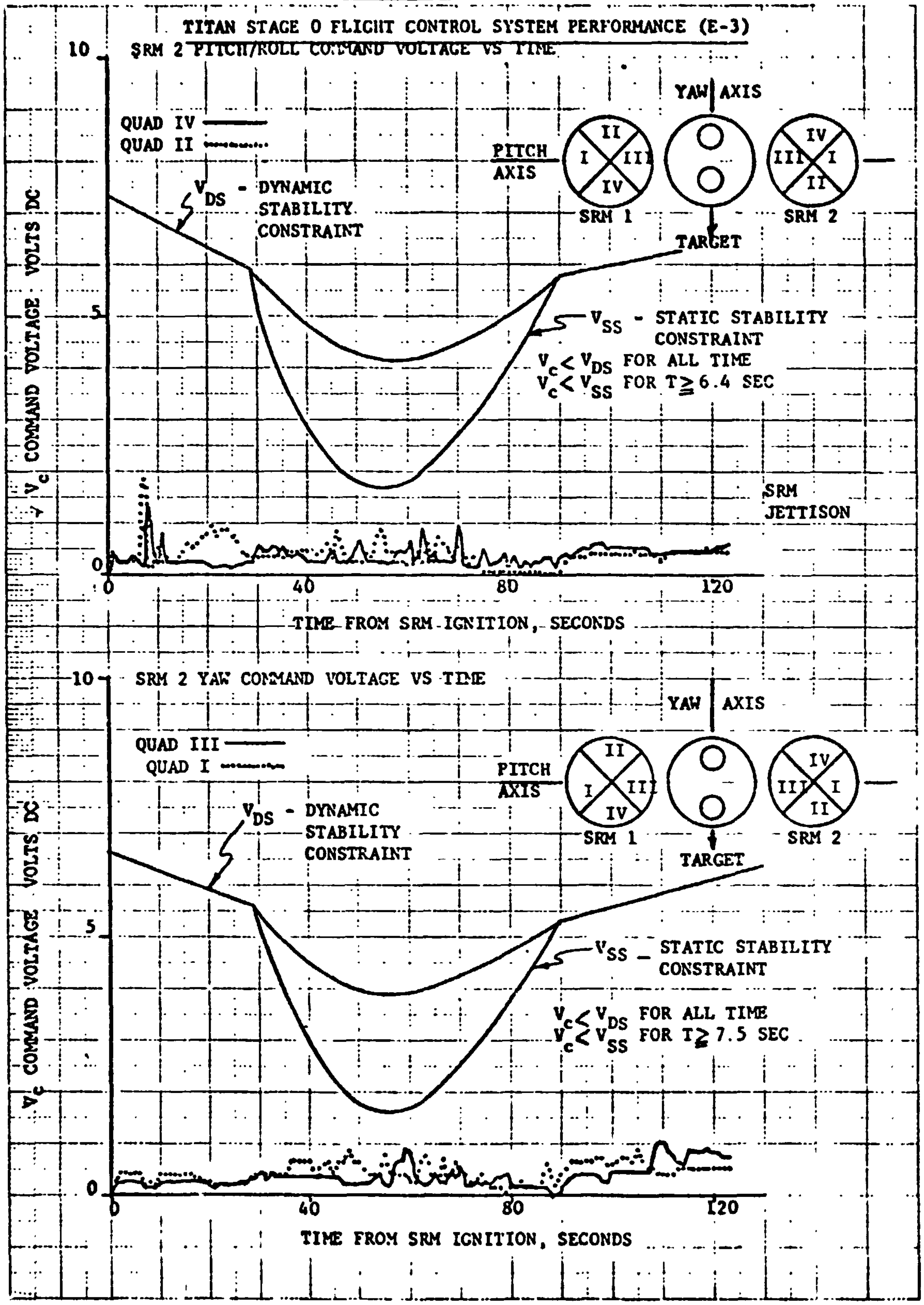
The control system response to vehicle dynamics was evaluated for each significant flight event. The amplitude, frequency and duration of vehicle transients, and the control system command capability required is shown in Table 7-7.

FIGURE 7-4 -



TITAN STAGE 0 FLIGHT CONTROL SYSTEM PERFORMANCE (E-3)
SRM 1 PITCH/ROLL COMMAND VOLTAGE VS TIME
QUAD IV
QUAD II
V_{DS} - DYNAMIC STABILITY CONSTRAINT
PITCH AXIS
YAW AXIS
II
I
III
IV
SRM 1
IV
III
I
II
SRM 2
TARGET
V_{SS} - STATIC STABILITY CONSTRAINT
$V_c < V_{DS}$ FOR ALL TIME
$V_c < V_{SS}$ FOR $T \geq 6.4$ SEC
SRM JETTISON
V_c COMMAND VOLTAGE VOLTS DC
10
5
0
0
40
80
120
TIME FROM SRM IGNITION, SECONDS
SRM 1 YAW COMMAND VOLTAGE VS TIME
QUAD III
QUAD I
V_{DS} - DYNAMIC STABILITY CONSTRAINT
PITCH AXIS
YAW AXIS
II
I
III
IV
SRM 1
IV
III
I
II
SRM 2
TARGET
V_{SS} - STATIC STABIL. CONSTRAINT
$V_c < V_{DS}$ FOR ALL TIME
$V_c < V_{SS}$ FOR $T \geq 7.5$ SEC
SRM JETTISON
V_c COMMAND VOLTAGE VOLTS DC
10
5
0
0
40
80
120
TIME FROM SRM IGNITION, SECONDS

FIGURE 7-5 -



TITAN STAGE 0 FLIGHT CONTROL SYSTEM PERFORMANCE (E-3)
SRM 2 PITCH/ROLL COMMAND VOLTAGE VS TIME
QUAD IV
QUAD II
V_DS - DYNAMIC STABILITY CONSTRAINT
PITCH AXIS
YAW AXIS
SRM 1
SRM 2
TARGET
V_SS - STATIC STABILITY CONSTRAINT
V_c < V_DS FOR ALL TIME
V_c < V_SS FOR T ≥ 6.4 SEC
SRM JETTISON
V_c COMMAND VOLTAGE VOLTS DC
TIME FROM SRM IGNITION, SECONDS
SRM 2 YAW COMMAND VOLTAGE VS TIME
QUAD III
QUAD I
V_DS - DYNAMIC STABILITY CONSTRAINT
PITCH AXIS
YAW AXIS
SRM 1
SRM 2
TARGET
V_SS - STATIC STABILITY CONSTRAINT
V_c < V_DS FOR ALL TIME
V_c < V_SS FOR T ≥ 7.5 SEC
V_c COMMAND VOLTAGE VOLTS DC
TIME FROM SRM IGNITION, SECONDS

TABLE 7-7 - VEHICLE DYNAMIC RESPONSE

EVENT	TIME SEC.	AXIS	ZERO TO PEAK AMPLITUDE Deg./Sec.	TRANSIENT FREQUENCY Hz	TRANSIENT DURATION Sec.	REQUIRED CONTROL 0/0 of Capacity
Roll Maneuver	7.8	R	4	.3	6	29.7
SRM Jettison (Initial Conditions)	120 - 123	R	.96	Drift	3	8
SRM Jettison Transient	124	R	7.9	.33	6	10
Start of PR 7 (Only Pitch Up Program)	130	P	1.2	N/A	N/A	12
Enable Guidance Steering (2^o PD $.3^o$ YR)	148.5 148.5	P Y	1.2 .3	N/A N/A	7 2.5	12 8
CSS Jettison	271.5 271.5 272 - 274 274.5	P R R R	.12 1 .72 .96	.5 $\approx$10 3 N/A	5 .6 2 2	4 4 16.5 25
Enable Guidance Steering (2.9^o PU, $.2^o$ YR)	300	P	1.32	.2	7	19.4

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Both flight programmers and the staging timer issued all preprogrammed discretes at the proper times. The Centaur sent four discretes to the Titan at the proper times. The complete sequence of events with actual and nominal times from SRM ignition is shown in Table 7-8.

TABLE 7-8 - E-3 FLIGHT SEQUENCE OF EVENTS

T-0 = 18:38:59.956 (SRM Ignition Command)

(Times from T-0)

Event	Predicted	F/F A	F/P B	S/T	DCU	Other	Delta
Start Roll Program	6.50				6.570		+0.070
Stop Roll Program	6.869				6.930		+0.061
Pitch Rate 1	10.000	10.004	10.004				+0.004
Pitch Rate 2	20.000	20.013	20.013				+0.013
Gain Change 1	29.000	29.018	29.018				+0.018
Pitch Rate 3	30.000	30.020	30.020				+0.020
Pitch Rate 4	62.000	62.043	62.043				+0.043
Gain Change 2	70.000	70.047	70.047				+0.047
Pitch Rate 5	75.000	75.049	75.051				+0.049
Enable S/T	75.000		75.052				+0.052
Gain Change 3	90.000	90.061	90.063				+0.061
Pitch Rate 6	95.000	95.066	95.067				+0.066
Enable F/P B	96.000		96.068				+0.068
Stage I Start CMD	109.386		110.969	111.114			+1.583
Stage I Start	110.150					111.722	+1.572
En Stg I ISDS Safe	115.386		116.980				+1.594
O/I Separation CMD	121.386		122.983	123.144			+1.597
O/I Separation	121.471					122.997	+1.526
En Stg I ISDS Safe	121.392	123.144					+1.752
Pitch Rate 7	129.186	130.089	130.787				+0.903
Pitch Rate 9	139.186	140.097	140.795				+0.911
Gain Change 5	191.386	192.133	193.032				+0.747
Gain Change 6	231.386	232.161	233.060				+0.775
Stg I S/D En	244.386	245.172	246.072				+0.786
Stg I S/D/Stg II Start	257.274					260.945	+3.671
I/II Separation	257.970					262.725	+4.755
CSS Sep Prim	267.970				271.659		+3.689
CSS Sep Sec	268.470				272.159		+3.721
CSS Sep B/U	286.970			290.691			+1.031
Remove GC7, PRIO	309.186	310.217	310.919				+3.689

TABLE 7-8 - E-3 FLIGHT SEQUENCE OF EVENTS (CONTINUED)

(Times from T-0)

Event	Predicted	F/P A	F/P B	S/T	DCU	Other	Delta
Gain Change 8	339.386	340.236	341.137				+0.850
Gain Change 9	399.386	400.277	401.181				+0.891
Stage II S/D En	446.486	448.313	448.318				+1.827
Stage II S/D	464.025				469.395		+5.370
Stage II S/D	464.648	469.778					+5.130
Stg II/Cen Sep	469.200				473.254		+4.054
Stg II/Cen Sep B/U	471.425	477.193					+5.768

Titan Electrical/Electronic Systems

Solid Rocket Motor Electrical System

by B. L. Beaton

Summary

For TC-3 the Solid Rocket Motor (SRM) system was identical to that flown on TC-1, TC-2 and TC-4. The SRM electrical system performance was satisfactory with no anomalies. All power requirements of the SRM electrical system were satisfied.

Discussion

The SRM electrical system supplied the requirements of the dependent systems at normal voltage levels. The SRM electrical system performance is summarized in Table 7-9.

The Titan core transfer shunt indicated 6.25 amps for approximately 400 ms at SRM ignition. This condition was experienced on TC-1, TC-2 and TC-4. It is caused by a short from an SRM igniter bridgewire positive to structure and simultaneous shorting from the transient return to readiness return within the igniter safe and arm device. The tran fer current dropped to zero simultaneous with the removal of the current path wh n the SRM umbilicals were ejected. This condition had no adverse effect on any airborne system.

TABLE 7-9 - SRM ELECTRICAL SYSTEM PERFORMANCE SUMMARY

		POWER ON INTERNAL	LIFTOFF	SRM JETTISON
TVC VOLTAGE	SRM-1	31.0	31.8	31.8
	SRM-2	31.6	32.0	32.0
AIPS VOLTAGE	SRM-1	29.8	29.8	29.6
	SRM-2	29.8	29.8	29.8
INSTRUMENTATION REGULATED BUS VOLTAGE	SRM-1	10.1	10.1	10.1
	SRM-2	10.0	10.0	10.0

Titan Core Electrical System

by B. L. Beaton

Summary

The Titan electrical system was identical to that flown on TC-1, TC-2 and TC-4. The core electrical system performance was satisfactory with no anomalies. All power requirements of the core electrical system were satisfied. All voltage and current measurements indicated expected values. Some bridgewire shorting (after initiation) was observed at every ordnance event.

Discussion

The Titan core electrical system supplied the requirements of the dependent systems at normal voltage and current levels. The Titan core electrical system performance is summarized in Table 7-10.

The 800 Hz squarewave output of the static inverter was 38.1 volts during the entire flight.

The TPS bus voltage was 35.9 volts d-c at TPS bus enable and 35.4 volts d-c at Titan/Centaur staging. The bus voltage was 3 to 4 volts higher than seen on TC-1 and TC-2 due to the topping off charge applied to the TPS battery after activation.

The TPS bus voltage and pyrotechnic firing currents during ordnance events are summarized in Table 7-11.

The transfer current indicated 6.25 amps at T-0 as previously discussed under SRM electrical system performance. The transfer current indicated that during short periods of high current demand on the APS bus, the IPS battery provided load sharing. This occurred at TPS enable, Stage I engine start and Stage I/II separation.

TABLE 7-10 - TITAN CORE VEHICLE ELECTRICAL SYSTEM PERFORMANCE SUMMARY

	POWER ON INTERNAL	LIFTOFF	ENABLE TPS	STAGE I START	STG 0/I SEP	STG I/II SEP	CSS JETTISON	STAGE II S/O	T/C STAGING
APS Voltage	28.0	28.5	28.0	27.3	27.8	27.2	28.0	28.0	27.8
APS Current	7.5	7.5	8.0	9.5	9.8	12.5	7.5	8.0	9.0
IPS Voltage	28.7	29.2	28.9	28.7	28.7	28.7	28.7	28.8	28.8
IPS Current	10.0	9.7	9.8	10.0	10.0	10.0	9.0	9.0	9.0
Transfer Current	0	6.25	0.6	0.5	0	0.6	0	0	0
TPS Voltage	0	0	35.9	35.9	35.6	35.4	35.9	35.4	35.4

TABLE 7-11 - TITAN CORE VEHICLE PYROTECHNIC SYSTEM

	STAGE I START	STG 0/I SEF	STAGING MOTORS	STG I/II SEP	CSS JETTISON	T/C STG & RETRO ROCKETS	T/C STAGING
TPS Voltage	28.7	27.1	27.1	27.9	29.6	30.8	30.8
TPS Current	33.5	172.4	225.1	268.2	33.3	71.8	27.0

Titan Instrumentation and Telemetry System

by R. E. Orzechowski

During the TC-3 flight a total of 197 measurements were telemetered by the Titan Remote Multiplexed Instrumentation System (RMIS). A summary of the type of measurements against the systems in which they were monitored is given in Table 7-12. Of these 197 measurements, all but 5 performed without any anomalies.

The following accelerometer measurements exhibited almost continuous high amplitude, low frequency spikes during Stage I engine operation.

1549	Oxidizer Pump Accel. SA-1
1550	Oxidizer Discharge Line Accel. SA-1
1552	Oxidizer Pump Accel. SA-2
1553	Oxidizer Discharge Line Accel. SA-2

All the above anomalies were attributed to the accelerometers being sensitive to high frequency inputs which produce low frequency outputs. The data from these accelerometers is only partially usable.

Measurement 2306, Stage I Longitudinal Accelerometer, exhibited erratic output throughout the flight. The output was attenuated and had a level shift at T + 232 seconds. The required data was provided by a similar accelerometer on Stage II.

Adequate telemetry coverage of the Titan vehicle was provided from lift-off to beyond Titan/Centaur separation. A summary of the predicted data coverage against actual data coverage of the Titan telemetry link is given in Table 7-13.

TABLE 7-12 - TITAN BOOSTER MEASUREMENT SUMMARY

SYSTEM / TYPE OF MEAS.	ACCELERATION	CURRENT	VOLT	PRESSURE	TEMPERATURE	DISPLACEMENT	RATE	DISCRETES	TOTAL
AIRFRAME	5			1				2	8
RANGE SAFETY									9
ELECTRICAL		10	15						25
HYDRAULIC				8		2			10
PROPULSION	6			34	8			4	52
FLT. CONTROL			33			32	11	10	86
TELEMETRY			6		1				7
TOTAL	11	10	57	43	9	34	11	22	197

TABLE 7-13 - SUMMARY OF PREDICTED DATA COVERAGE VERSUS ACTUAL DATA COVERAGE

TITAN 2287.5 MHZ LINK

STATION	PREDICTED AOS	PREDICTED LOS	ACTUAL	
CIF (MAINLAND)	TURN ON	450	TURN ON	489
GBI (GRAND BAHAMA)	47	506	45	535

Flight Termination System

by R. E. Orzechowski

The Titan flight termination system performance was nominal throughout the flight. Monitoring of the receiver AGC voltages by telemetry indicated that sufficient signal was present throughout the powered flight to assure that any destruct or engine shutdown commands would have been properly executed. A safe command was sent by the Range from Antigua at 1849:24Z. A list of station switching times is given in Table 7-14.

The Range Safety Command battery voltages were 32.7 volts d-c at lift-off and remained steady throughout the flight. The commands from the flight programmer to safe the Stage I and two SRM Inadvertent Separation Destruct Systems (ISDS) were issued at their expected times. The flight programmer also issued the command to safe the Destruct Initiator on Stage II prior to the Titan/Centaur separation.

TABLE 7-14 - STATION SWITCHING TIMES

STATION	CARRIER ON	CARRIER OFF
MAINLAND (STA. 1)	1800:31 Z	1841:52 Z
GRAND BAHAMA IS. (STA. 3)	1841:50 Z	1846:41 Z
ANTIGUA (STA. 91)	1841:41 Z	1849:47 Z

VIII CENTAUR D-1T SYSTEMS ANALYSIS

VIII CENTAUR D-1T SYSTEMS ANALYSIS

Mechanical Systems

Airframe Structures

by R. T. Barrett and R. C. Edwards

Summary

The Centaur D-1T structural configuration for the TC-3 vehicle was similar to the TC-1 vehicle. The ISA satisfactorily transferred all Centaur and CSS loadings onto the Titan skirt structure. The ISA forward ring was completely severed at Titan/Centaur staging and the vehicles separated at a constant acceleration.

The ullage pressures in the Centaur propellant compartments were within prescribed limits. Sufficient pressure was maintained to prevent buckling and maximum pressures did not exceed burst limits of the tank structure.

Discussion

Interstage Adapter: Titan/Centaur separation occurred at T + 473.254 seconds. Initial motion was at approximately T + 473.4 seconds. The interstage adapter cleared the Centaur vehicle 1.92 seconds after separation. The 15-foot extensiometer (yo-yo) between the ISA and the Centaur indicated a smooth normal separation (Figure 8-1).

Centaur Tank: The liquid hydrogen tank pressure was always less than the maximum allowable pressure of 29.2 psid.

Sufficient pressure was maintained in the liquid hydrogen tank to prevent compressive buckling of the pressure stabilized tank skin for all periods of flight. During the critical compressive loading at lift-off, the pressure was 23.9 psia. The hydrogen tank pressure during the aerodynamic phase of flight (T + 10 to T + 90 seconds) was similar to previous Titan/Centaur flights and provided sufficient compressive strength.

The liquid oxygen tank pressure was within the structural limits for all periods of flight.

The differential pressure across the intermediate bulkhead did not exceed the structural limit of 23.0 psi. As required, the oxygen tank pressure was always greater than the hydrogen tank pressure.

The liquid hydrogen and oxygen tank ullage pressure time histories are listed in the Centaur D-1T pneumatics section of this report. See Figures 8-3.1, 8-3.2 and 8-3.3.

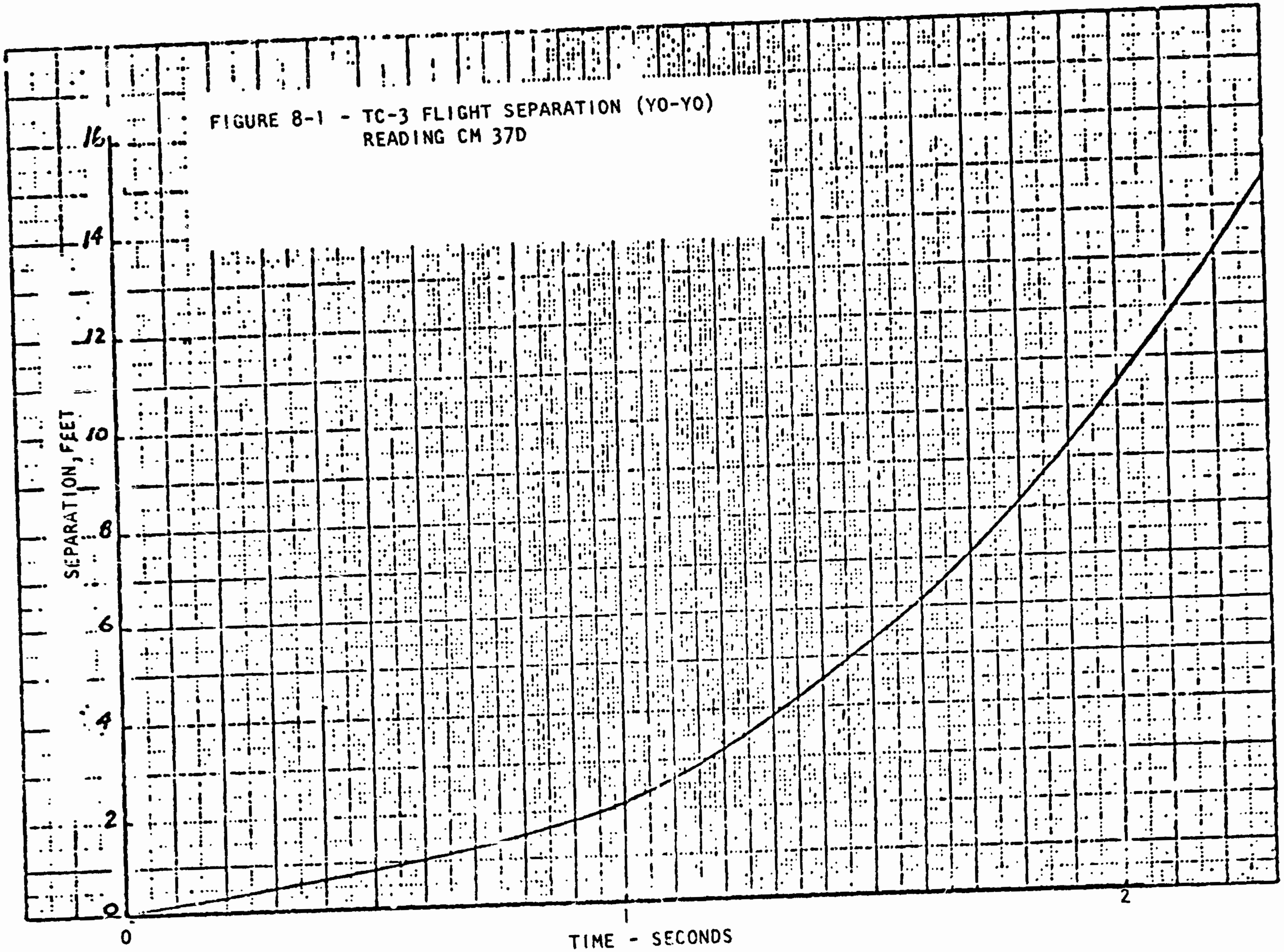

FIGURE 8-1 - TC-3 FLIGHT SEPARATION (YO-YO)
READING CM 37D

Centaur Main Propulsion

by W. K. Tabata

Summary

Centaur main propulsion prelaunch operations were normal. Engine performance in flight was normal and steady-state performance agreed well with engine acceptance test values. No anomalies outside of previous Centaur flight experience were encountered.

Discussion

Liquid Helium Prechill: Liquid helium prechill of the main engine fuel pumps (Table 8-1) was satisfactory. The C-1 and C-2 engine fuel pump housing temperatures CP60T and CP62T were below the 100°R redline from T-20 minutes until liftoff on both engines. At liftoff, CP60T and CP62T were 60°R and 68°R, respectively.

First-Burn: First-burn prestart, start transient, steady-state and shutdown transients were normal. C-1 and C-2 fuel and oxidizer pump housing temperatures at the beginning of first-burn prestart were as expected (Table 8-2). The pump housing temperature probes were slow in responding to pump cooldown during prestart, but this is a characteristic of the temperature probe previously experienced in flight.

Acceleration time (MES to 90% steady-state chamber pressure) was 1.32 seconds for both the C-1 and C-2 engines.

Steady-state engine parameters measured at MES #1 + 110 seconds are compared to acceptance test values in Tables 8-3 and 8-4. The comparison is excellent. Actual first-burn time was 129.3 seconds. (Predicted burn time was 128.3 seconds). First-burn shutdown transients were normal.

Second-Burn: The second-burn prestart was normal. Engine pump housing temperatures (Table 8-2) were as expected at the beginning of prestart. All pump housing temperature probes again exhibited slow response.

Second-burn start transients were normal. The engine acceleration times for C-1 and C-2 engines were both 1.40 seconds.

Steady-state performance is listed in Tables 8-3 and 8-4 and comparison to acceptance test is excellent. Actual second-burn time was 302.0 seconds. (Predicted burn time was 306.2 seconds). Second-burn shutdown transients were normal.

TABLE 8-1 - TC-3 PRELAUNCH THERMAL CONDITIONING OF RL10 ENGINES

a) Time to Liquid Indication at Pump Inlets

MEAS. NUMBER	DESCRIPTION	UNITS	TIME FROM START OF TANKING UNTIL LIQUID INDICATION AT ENGINE PUMP INLETS	
			TCD	LAUNCH
Oxidizer Pumps				
CP59T	C-1 Pump LOX Inlet	Minutes	8.4	7.2
CP61T	C-2 Pump LOX Inlet	Minutes	8.9	7.8
Fuel Pumps				
CP60T	C-1 Pump LH2 Inlet	Minutes	7.3	6.8
CP62T	C-2 Pump LH2 Inlet	Minutes	7.0	6.7

b) Liquid Helium Childown of Engine Fuel Pumps

MEAS. NUMBER	DESCRIPTION	UNITS	TIME FROM START OF LHe CHILLDOWN UNTIL FUEL INLET PUMP TEMPERATURE = 360°F	
			TCD	LAUNCH
CP122T	C-1 Engine Fuel Pump	Minutes	12.5	9.7
CP123T	C-2 Engine Fuel Pump	Minutes	12.3	10.6

TABLE 8-2 - TC-3 ENGINE AND OXIDIZER PUMP HOUSING TEMPERATURES AT PRESTART

MEAS. NUMBER	DESCRIPTION	UNITS	FIRST BURN		SECOND BURN	
			EXPECTED VALUES	ACTUAL	EXPECTED VALUES	ACTUAL
Engine Fuel Pump						
CP122T	C-1 Engine Fuel Pump	DGF	190 - 200	198	190 - 240	223
CP123T	C-2 Engine Fuel Pump	DGF	190 - 200	195	190 - 240	231
Engine Oxidizer Pump						
CP124T	C-1 Engine LOX Pump	DGF	370 - 430	386	300 - 400	333
CP125T	C-2 Engine LOX Pump	DGF	370 - 430	389	300 - 400	390

TABLE 8-3 - TC-3 RL10 ENGINE STEADY STATE PERFORMANCE PARAMETERS

MEAS. NUMBER	DESCRIPTION	UNITS	ACCURACY	EXPECTED VALUE AT O/F = 5.0	ENGINE FIRING SEQUENCE	
					FIRST BURN	SECOND BURN
CP1B	C-1 Pump Speed	rpm	± 600	12,335	12,260	12,350
CP[illegible]	C-2 Pump Speed	rpm	± 600	12,496	12,450	12,470
CP7P	C-1 Fuel Venturi Inlet	psia	± 30	745	730	750
CP8P	C-2 Fuel Venturi Inlet	psia	± 30	747	745	755
CP46P	C-1 Thrust Chamber	psia	± 10	392	392	390
CP47P	C-2 Thrust Chamber	psia	± 10	394	398	392
CP107P	C-1 Pump LOX Disch.	psia	± 16	619	615	625
CP10[illegible]	C-2 Pump LOX Disch.	psia	± 16	623	625	620
CP5T	C-1 Turbine Inlet	DGR	± 16	377	380	385
CP6T	C-2 Turbine Inlet	DGR	± 16	386	380	380

TABLE 8-4 - TC-3 CENTAUR MAIN PROPULSION PERFORMANCE

PARAMETER	P&WA ACCEPT. TEST	FIRST BURN MES #1 + 100 SEC.	SECOND BURN MECO #2
C-1 Thrust, pounds	14,997	14,977	14,919
C-2 Thrust, pounds	15,012	15,026	14,959
C-1 Mixture Ratio, O/F	5.02	4.98	4.91
C-2 Mixture Ratio, O/F	4.99	4.98	4.90
C-1 Specific Impulse, seconds	441.6	441.8	442.0
C-2 Specific Impulse, seconds	442.0	442.0	442.3

NOTE: Flight performance calculated by P&WA C* iteration computer program

Centaur Hydraulic System

by T. W. Godwin

Summary

Centaur hydraulic system performance was normal throughout the TC-3 flight. The recirculation pumps functioned properly prior to engine starts and during the blowdown maneuver. There were no anomalies, but an unusual amount of steering corrections were noted following guidance enable after MES #1.

Discussion

System pressures and temperatures are presented in Table 8-5. All parameters were normal throughout the countdown and flight. A maximum temperature of 166°F was noted on the manifolds just prior to MECO #2. The recirculation pumps functioned normally when commanded ON prior to MES #1, MES #2 and during the blowdown maneuver. There were no system anomalies.

Following guidance enable after Titan/Centaur separation and MES #1, eight maximum velocity cycles were observed on the yaw/roll actuators. The pitch actuators cycled four times at less than maximum velocity, followed by six maximum velocity cycles. This amount of initial steering correction was less than that experienced on TC-4 but greater than the four or five cycles usually observed. These unusually severe steering commands are attributed to a 15° tilt of the Centaur vehicle after separation and a software limitation of the maximum gimbal angle to ± 2°. The initial tilt of the TC-3 vehicle was less than that of TC-4, which accounts for the somewhat less severe cycling of the TC-3 steering system. During these short periods of maximum demand, the hydraulic pressure dropped to 300 psia, followed by an immediate recovery to normal system pressure. This characteristic is normal. Actuator response was also normal.

TABLE 8-5 - CENTAUR HYDRAULICS SYSTEM - TC-3

Flight Sequence	Parameters	Hydraulic Pressure, psia Expected Values (approx.)	Hydraulic Pressure, psia CH 1P C-1 Engine	Hydraulic Pressure, psia CH 3P C-2 Engine	Manifold Temp., °F Expected Values	Manifold Temp., °F CH 5T C-1 Engine	Manifold Temp., °F CH 6T C-2 Engine
Count	Max. during count				180 max.	111	111
First Burn	Prior to recirc. on				180 max.	65	58
	Recirc. motors on	120 - 140	120	135	"	65	58
	MES - 1	1110 -1150	1117	1123	"	67	60
	MECO - 1	1110 -1150	1117	1125	"	110	108
Second Burn	Prior to recirc. on				180 max.	88	87
	Recirc. motors on	120 - 140	120	127	"	88	87
	MES - 2	1110 -1150	1118	1132	"	89	88
	MECO - 2	1110 -1150	1110	1125	"	166	166
Blowdown	Recirc. motors on	120 - 140	120	120	180 max.	124	127
	Recirc. motors off	120 - 140	120	120	"	115	113

Centaur Pneumatics

by R. A. Corso and R. F. Lacovic

Summary

The pneumatic system performed satisfactory throughout the TC-3 flight. The tank pressures and propulsion pneumatic control pressures were satisfactory. The LH_2 tank pressure at liftoff was 23.9 psia which was within the allowable limits of 23.1 to 24.9 psia. There was no evidence of LO_2 tank pressure oscillations during second burn pressurization as was experienced on TC-4.

Discussion

Configuration: The Centaur pneumatic system which is shown schematically in Figure 8-2 was the same as TC-4 except for the addition of the zero-g purge. The purge initiates downstream of the engine control regulator and provides a low flow purge to the LOX tank standpipe, pressure sense line and the hydrogen tank pressurization line. The zero-g purge was installed as a result of the TC-4 anomaly to prevent liquid from entering the LOX tank pressure sense line. On TC-4 liquid entered the sense line and pressure oscillations developed which switched the pressurization system over to the backup system.

Propellant Tank Pressurization and Venting: Performance data for the pneumatic system during the flight are summarized in Table 8-6 and a time history of the propellant tank ullage pressures during the flight is shown in Figures 8-3.1, 8-3.2 and 8-3.3. Prior to lockup, the hydrogen tank pressure was 20.9 psia. The operating band of the primary hydrogen vent valve is 19 to 21.5 psia. At T-27.2 seconds, the primary hydrogen vent valve was commanded to the locked mode and the tank pressure was allowed to rise in order to satisfy the tank structural strength requirements during liftoff and during the subsonic portion of the flight.

At liftoff the minimum pressure requirement was 23.1 psia. A maximum liftoff pressure of 24.9 psia had also been established in order to preclude the possibility of venting hydrogen gas overboard before eight seconds into the flight.

From the time of vent valve lockup until T-8 seconds, the tank pressure was monitored by the computer controlled vent and pressurization system (CCVAPS), which calculated the pressure rise rate and predicted the tank pressure at liftoff. If the CCVAPS prediction had not fallen within the established limits (23.1 - 24.9 psia), an automatic launch abort would have been initiated. At T-8 seconds the CCVAPS predicted pressure at liftoff was 24.15 psia. The actual liftoff pressure was 23.94 psia. After the final liftoff pressure check at T-8 seconds, the CCVAPS was deactivated until start of tank pressurization for the first main engine start sequence

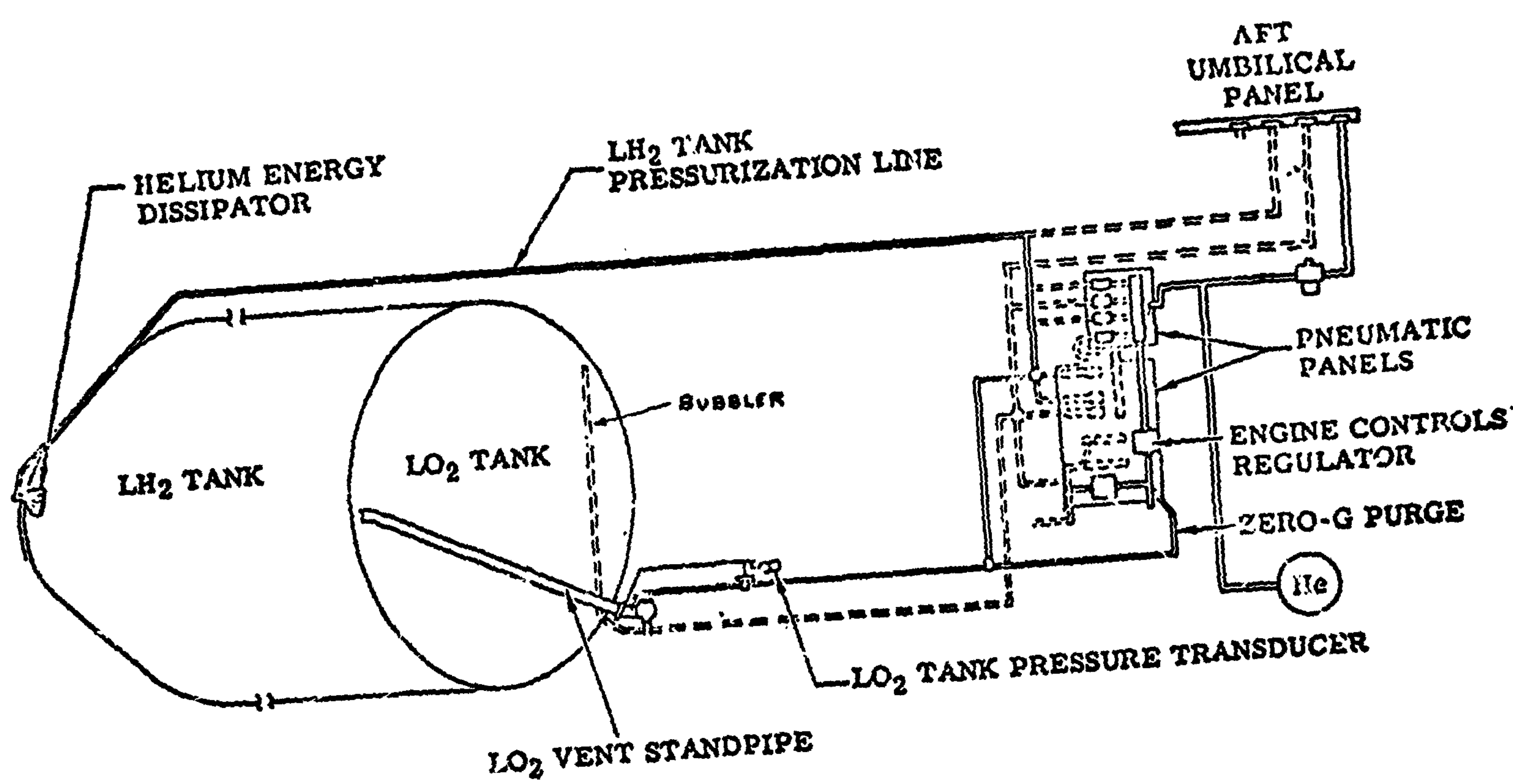

FIGURE 8-2 - CENTAUR PNEUMATIC AND ZERO-GRAVITY PURGE SYSTEM

TABLE 8-6 - PNEUMATIC SYSTEM DATA SUMMARY FOR TC-3

Meas. Number	Description	Units	Control Range	Start Auto Count	T-0	T+90 Sec.	Start Prztn. #1	Pre-star. #1	MES #1	MECO #1	Start Prztn. #2	MES #2	MECO #2
CF1P	LO2 Tank Ullage Press.	psia	29-32	30.7	30.7	29.6	30.6	39.0	37.8	29.9	32.1	35.6	25.1
CF6T	LO2 Tank Ullage Temp.	°F	ref. data	-284.0	-284.0	-284.2	-284.2	-282.2	-282.2	-286.1	-287.6	-282.7	-289.1
CF3P	LH2 Tank Ullage Press.	psia	19-21.5	20.9	23.9	24.8	19.6	26.8	25.7	18.3	19.8	23.2	12.6
CF100T	LH2 Tank Ullage Temp.	°F	ref. data	-428.6	-423.9	-407.6	-428.6	-374.2	-329.6	-368.3	OSL	-298.0	-365.2
CF18P	Eng. Ctl. Reg. Outlet Press.	psig	440-475	444.6	444.6	447.2	447.2	446.0	447.2	447.2	452.0	458.1	458.1
CF110P	Att. Ctl. Reg. Outlet Press.	psig	297-315	309.7	309.7	320.4	310.5	310.5	310.5	310.5	303.7	306.5	309.7
CF2P	Helium Bottle Press.	psia	3180-3350	3290	3291	3283	3238	2958	2852	2870	2947	1978	2100
CF4T	Helium Bottle Temp.	°F	50-85	77	77	77	74.8	59.2	57.0	56.0	63.7	21.2	39.1
CF134T	Aft Pneu. Panel #2	°F	ref. data	68	61	58	54	56	56	56	97.4	94.6	75.8

*Approximately 7 seconds prior to start of tank pressurization. Data loss during start of tank pressurization sequence.

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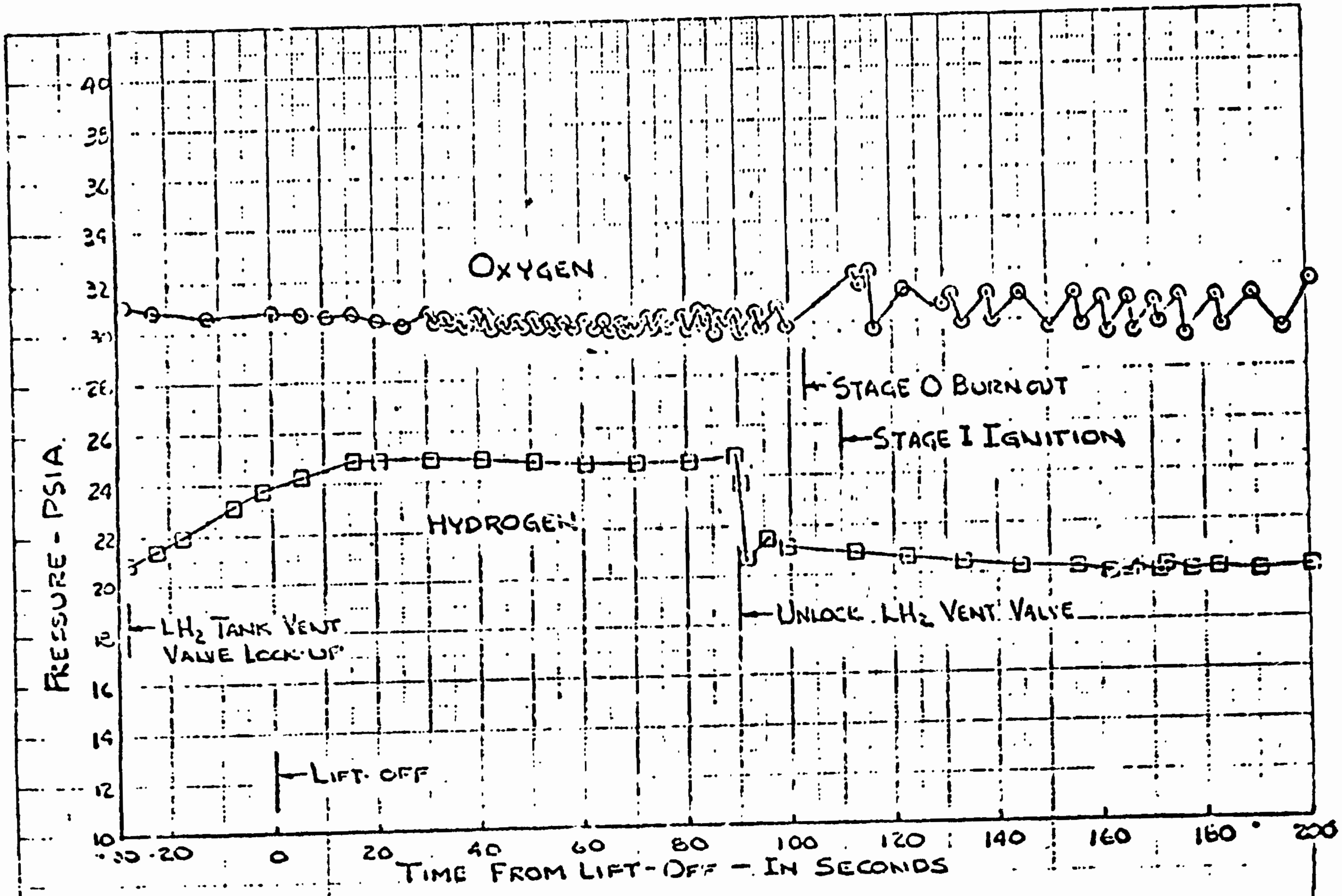

FIGURE 8-3.1 - CENTAUR TANK ULLAGE PRESSURE TIME HISTORY

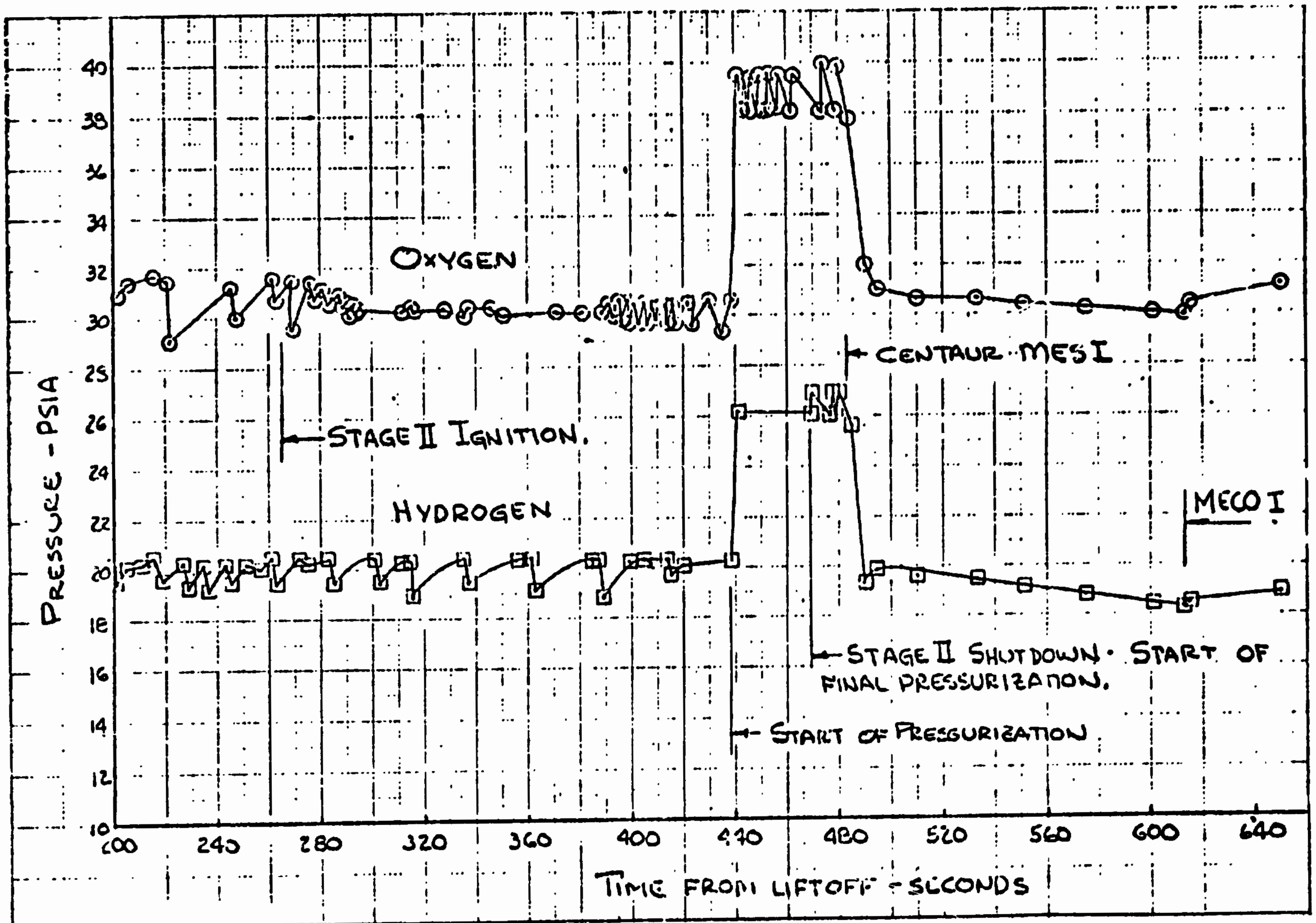

FIGURE 8-3.2 - CENTAUR TANK ULLAGE PRESSURE TIME HISTORY (CONTINUED)

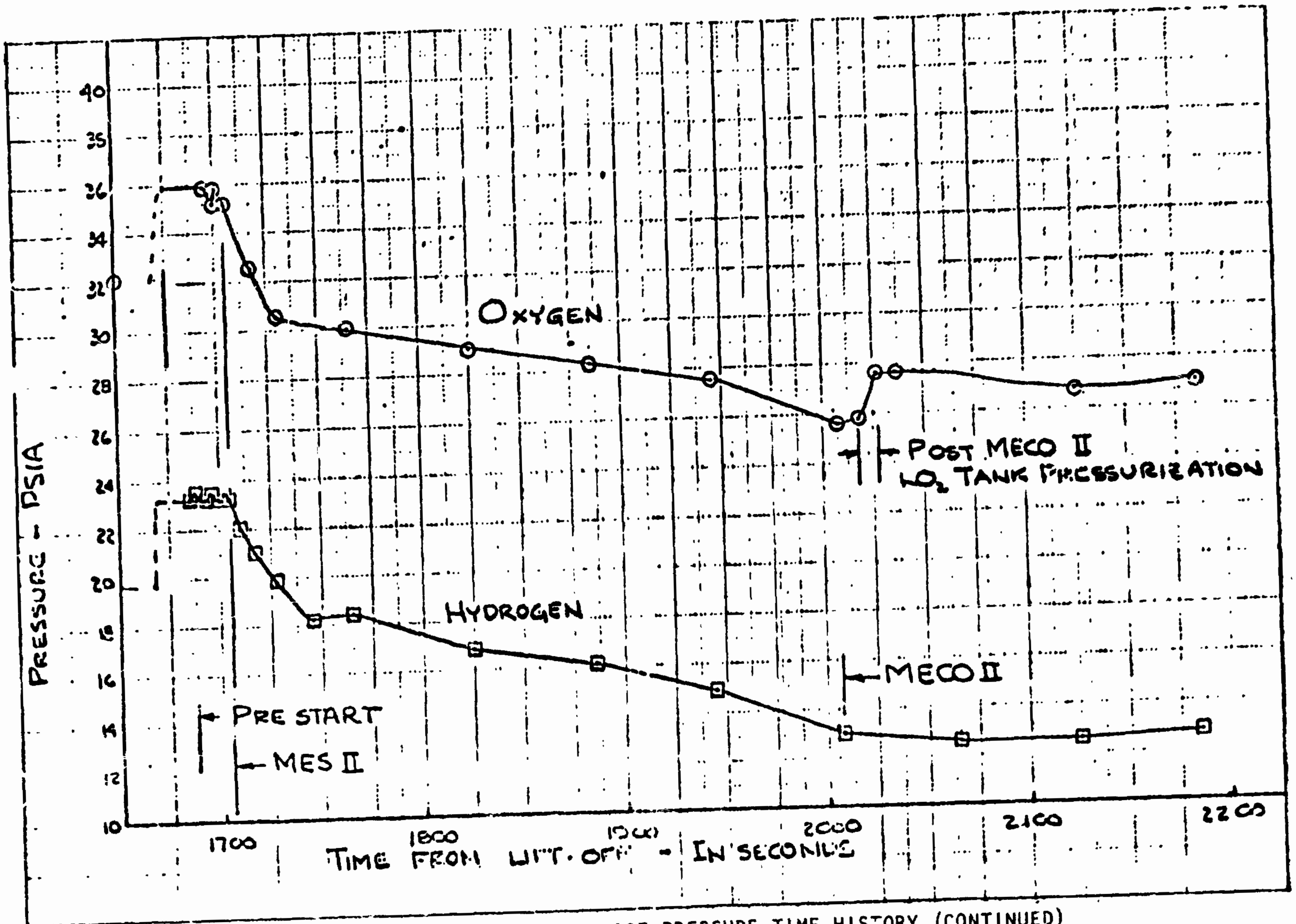

FIGURE 8-3.3 - CENTAUR TANK ULLAGE PRESSURE TIME HISTORY (CONTINUED)

During the boost phase the tank pressure increased to a maximum of 24.9 psia. At T + 90 seconds the primary hydrogen vent valve was unlocked allowing the tank pressure to decay to the primary vent valve operating range. The tank pressure was controlled by the vent valve until commanded to the locked mode for the start of tank pressurization for the first main engine start. Operation of the vent valve was satisfactory although the tank pressure momentarily dipped 0.2 psi below its lower limit of 19.0 psia on two occasions. This phenomena has occurred on prior flights and may be attributed to vent valve response time in a hard vacuum. Ground testing also indicates lower reseat pressures when the valve vents to low pressures.

The oxygen tank pressure at liftoff was 30.7 psia. During the boost phase the oxygen tank vent valve relieved and cycled, maintaining the tank pressure between 29 and 32 psia. At Stages 0, I and II burnout and shutdown the reduction in vehicle acceleration caused an increase in the liquid oxygen boiloff and consequently increased tank pressure and vent valve activity.

At T + 439.2 seconds, both hydrogen vent valves and the oxygen vent valve were activated to the locked mode, and tank pressurization for the first main engine start sequence was initiated. CCVAPS controlled tank pressures to predetermined increases over the pressures at the start of pressurization. These increases in both tanks were based upon tank structural limits and boost pump net positive suction pressure requirements. The hydrogen tank pressure was increased from 20.3 to 25.5 psia; maximum pressure allowable was 27.0 psia. The tank pressure at main engine start (MES I) was 25.7 psia. The oxygen tank pressure was increased from 30.6 to 38.4 psia; maximum allowable pressure was 40.0 psia. The tank pressure at MES I was 37.8 psia. A discussion of the CCVAPS software and performance is presented in the CCVAPS section of this report.

At T + 483.6 seconds Centaur MES I was initiated. The pressures in both tanks dropped rapidly at first and then decayed gradually until first main engine cutoff (MECO I) at T + 613 seconds. The pressure in the hydrogen tank at MECO I was 18.3 psia while that in the oxygen tank was 29.9 psia. During the coast phase after MECO I, the pressures in the oxygen tank and hydrogen tank increased to 32.1 and 19.8 psia, respectively, at the beginning of tank pressurization for second main engine start (MES II).

At T + 1668 seconds the tank pressurization for MES II was initiated and controlled by CCVAPS. The hydrogen tank pressure was increased from 19.8 to 23.2 psia; maximum tank pressure was 23.4 psia. The oxygen tank pressure was increased from 32.1 to 35.6 psia, maximum pressure was 36.1 psia. Again, the tank pressures dropped rapidly at first and then gradually until MECO II, at which time the LO_2 pressure was 25.6 psia and the LH_2 tank pressure was 13 psia. After MECO II both tank pressures increased slightly. The oxygen tank was pressurized at MECO II + 10 seconds for eight seconds increasing the pressure 1.2 psid.

Helium Storage and Consumption: The helium stored in one 7365 cubic inch bottle was used to pressurize the propellant tanks during engine start sequences, to operate the engine control valves, to pressurize the H_2O_2 bottle and to provide purges to various components on the Centaur. The amount of helium consumed during the flight through post-MECO li oxygen tank pressurization is summarized in Table 8-7. It should be noted that the amount of helium used during engine start sequences includes usage for tank pressurization, pressurization of the H_2O_2 bottle and zero-g purges.

Propulsion Pneumatics: The engine control and attitude control regulators maintained proper system pressure levels from pressurization of the helium bottles through retromaneuver. The engine controls regulator output pressure at liftoff was 444.6 psig (allowable limits are 440 to 479 psig), while that of the H_2O_2 bottle pressure regulator was 309.7 psig (allowable limits are 297-316 psig). At the end of the available data, T + 3060 seconds, the engine controls regulator had drifted up to 468.1 psig. The attitude controls regulator remained relatively stabled at 309.7 psig.

Helium Purge: Throughout the launch countdown, the ground system supplied a helium gas purge to the forward and aft ends of the vehicle. The gas was used to purge the hydrogen tank/shroud annulus, the destruct package and several propulsion system components. The purge was required to maintain enough pressure differential across the shroud after cryogenic tanking to prevent ground wind inflow. For the launch day wind conditions of approximately 5 knots, a minimum differential pressure of 0.045 psid, was required. Minimum pressure during hydrogen tanking was 0.125 psid. At liftoff the pressure was 0.34 psid.

Computer Controlled Vent and Pressurization System (CCVAPS): For the LH_2 tank liftoff pressure check CCVAPS predicted a tank pressure at T-0 or 24.15 psia as compared with the actual value of 23.94 psia. This pressure was well within the required liftoff pressure gate of 23.1 to 24.9 psia. The LH_2 tank pressure history from LH_2 vent valve lockup at T-27.68 through the LH_2 tank vent at T + 90 is shown in Figure 8-4. This pressure history was normal and comparable to previous TC flight experience.

During the pre-MES 1 and pre-MES 2 tank pressurizations CCVAPS controlled the tank pressures to within the required operating ranges and control criteria. The pre-MES 1 and pre-MES 2 tank pressure histories are shown in Figures 8-5 and 8-6, respectively. The CCVAPS pressurization control parameters are summarized in Table 8-8. The LO_2 tank pre-MES 2 pressure oscillation anomaly which was observed on TC-4 did not occur on TC-3. The installation of the LO_2 tank pressure sense line purge apparently eliminated thi problem.

CCVAPS did not enable a venting of either propellant tank du ing the coast since the tan ressures were well below the tank vent initiation criteria as summarized in Table 8-9.

TABLE 8-7 - SUMMARY OF HELIUM USAGE, TC-3

Flight Event	Predicted Usage, Lbs.	Actual Usage, Lbs.	He Remaining, Lbs.
Bottle Storage Prior to Liftoff	8.6	8.3	8.3
MES I Pressurization	0.8	0.71	7.59
First Burn & Coast	0.2	0.42	7.17
MES II Pressurization	1.5	1.2	5.97
Second Burn & Post-MECO II Pressurization of LO_2 Tank	0.6	0.33	5.64

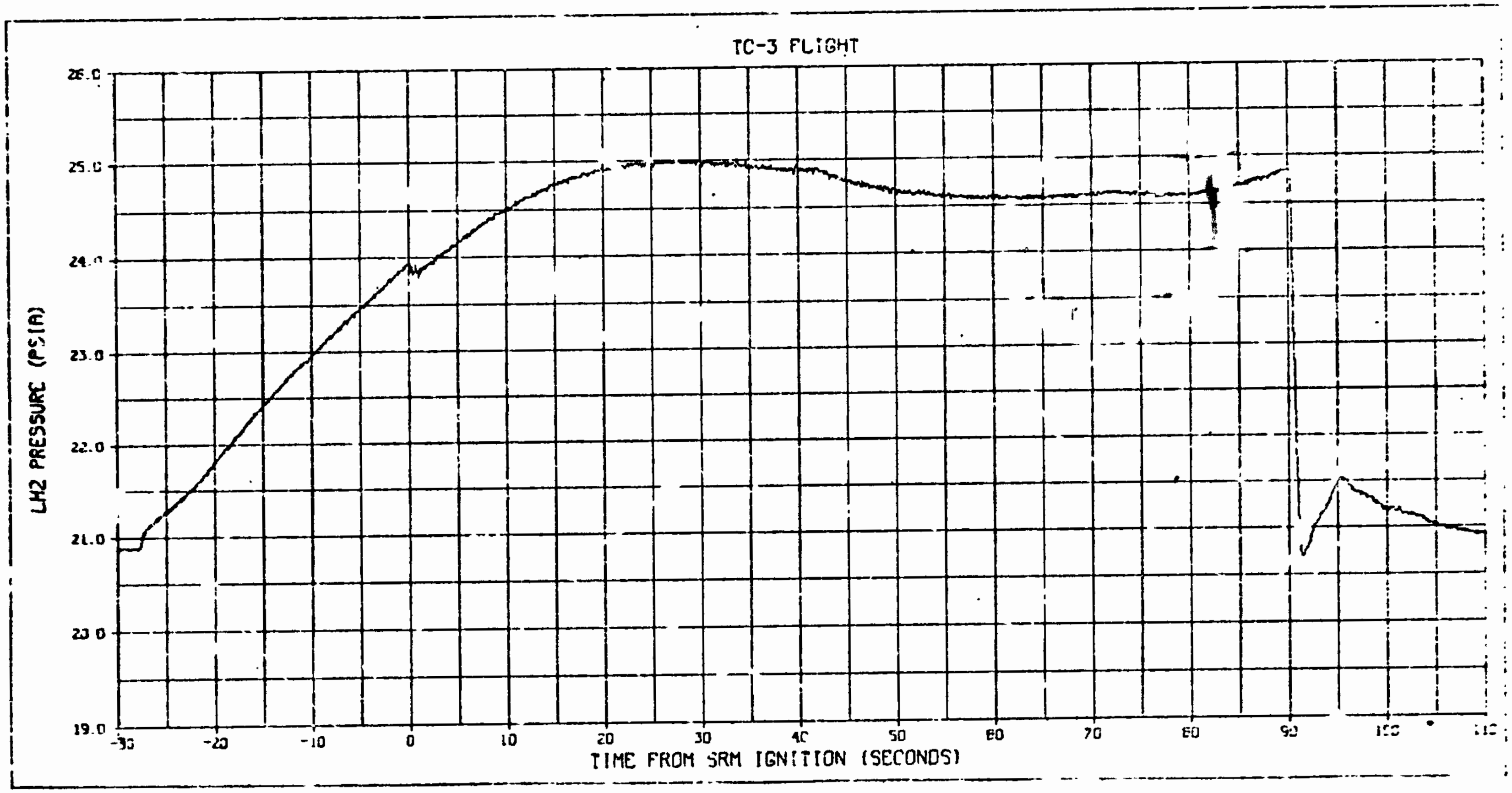

FIGURE 8-4 - LH_2 TANK PRESSURE HISTORY AT LIFTOFF

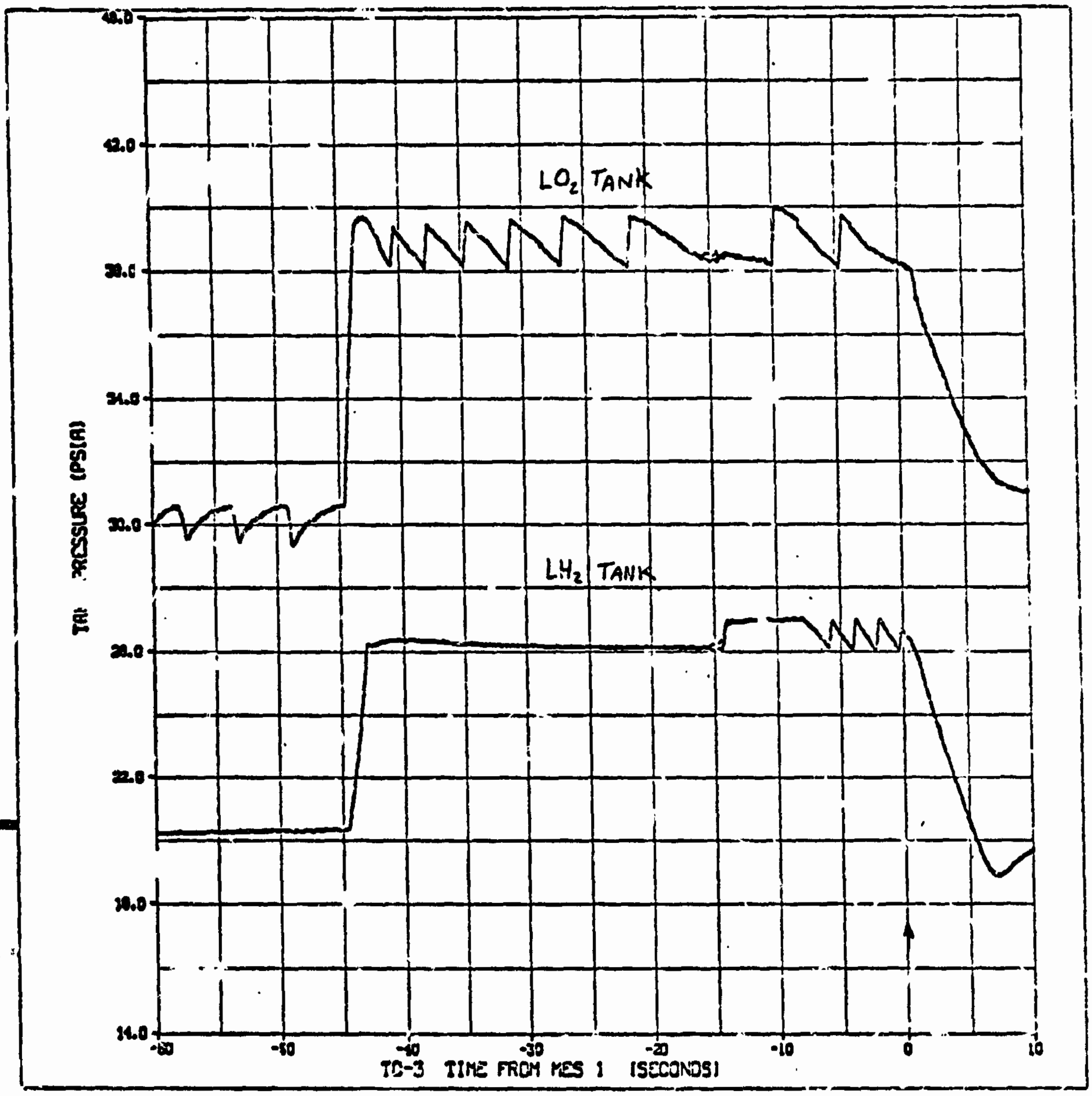

FIGURE 8-5 - TANK PRESSURE HISTORIES DURING FIRST PRESSURIZATION

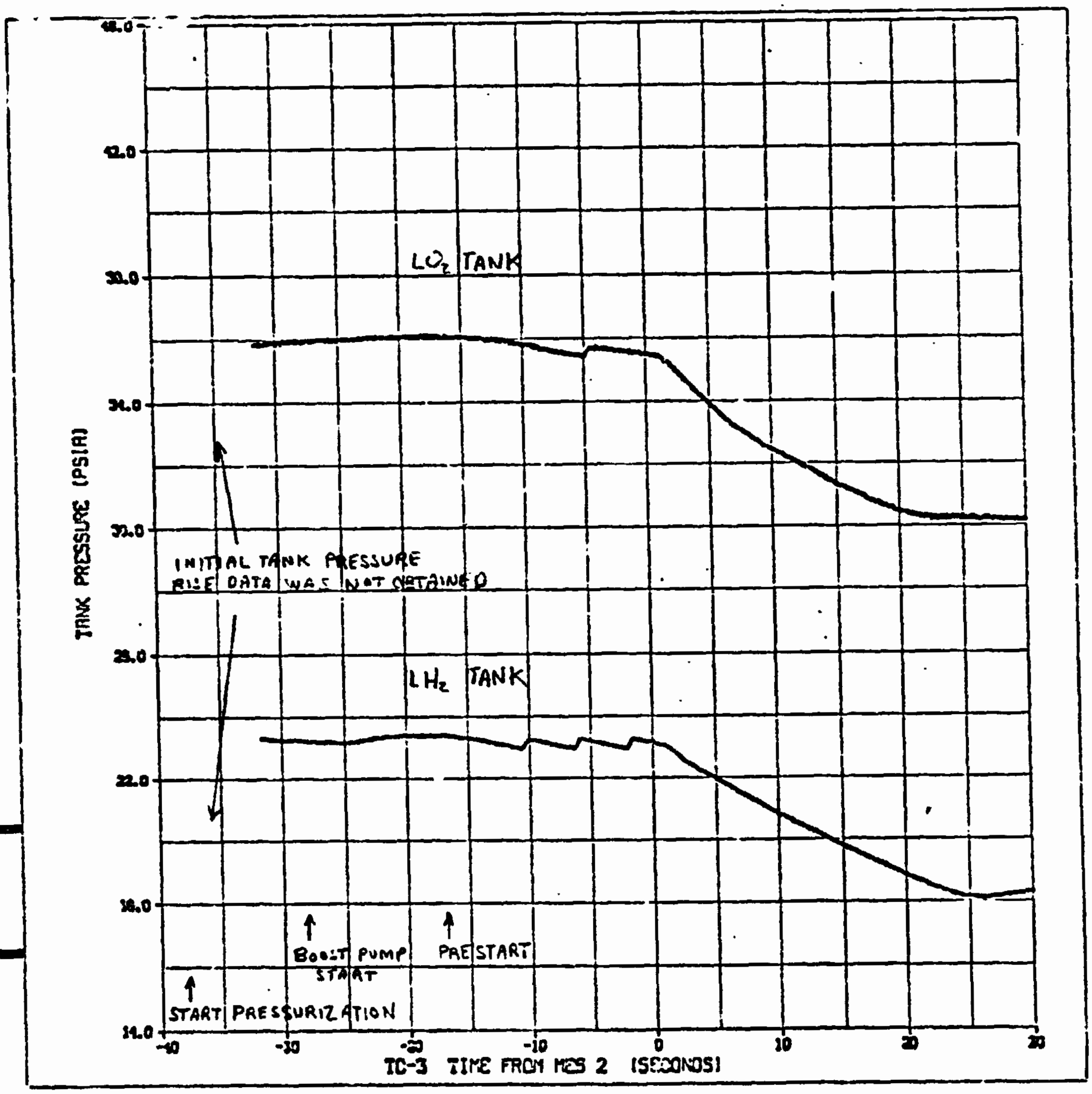

FIGURE 8-6 - TANK PRESSURE HISTORIES DURING SECOND PRESSURIZATION

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TABLE 8-8 - CCVAPS TANK PRESSURIZATION CONTROL PARAMETERS - TC-3

Parameters			LO2 Tank Pressures, psia			LH2 Tank Pressures, psia	
		TC-2	TC-3/4 Expected Values	TC-3	TC-2	TC-3/4 Expected Values	TC-3
Tank Pressurization Sequence for First MES							
Prior to Stage II Cutoff	initial pressure @ start of prztn.	32.15	29.0-32.7	30.61	19.92	19.0-21.5	20.31
	closing pressure	39.12	38.2-40.5	38.37	25.92	25.0-25.5	25.50
	closing pressure criteria	Δp max	---	Δp close	Δp close	---	Δp max
	minimum undershoot pressure	38.2	37.40 min	38.10	25.66	23.10 min	26.10
	maximum overshoot pressure	40.75	44.27 max	39.70	26.63	27.82 max	26.40
	initial pressure rise in 1.5 sec.	8.81	$\geq$1.33	9.10	2.73	$\geq$0.66	2.40
After Stage II Cutoff	closing pressure	39.91	38.2-40.5	38.37	25.92	25.0-26.6	26.31
	closing pressure criteria	Δp close	---	Δp close	Δp close	---	Δp max
	minimum undershoot pressure	39.87	37.4 min	38.07	26.05	23.1 min	26.11
	maximum overshoot pressure	41.6	44.27 max	40.00	26.60	28.92 max	27.19
Tank Pressurization Sequence for Second MES							
Initial pressure at start of prztn.		32.61	29.0-3[illegible].0	32.12	20.13	19.0-23.5	19.76
closing pressure		36.11	32.5-4[illegible].5	35.62	23.53	22.4-28.1	23.16
closing pressure criteria		Δp close	---	Δp close	Δp close	---	Δp close
minimum undershoot pressure		39.49	31.7 min	35.39	23.37	21.9 min	22.94
maximum undershoot pressure		40.30	48.27 max	36.13	23.65	28.4 max	23.26
Initial pressure rise in 2.0 seconds		1.21	$\geq$0.75	1.80	0.35	$\geq$0.18	1.20
Post-MECO-2 Tank Pressurization							
Initial pressure at start of prztn.		31.5	29.0-3[illegible].0	25.90			
closing pressure		26.8	26.8	26.80			
closing pressure criteria		p max	p max	p max			
minimum undershoot pressure		none	none	---			
maximum overshoot pressure		none	none	---			
Initial pressure rise in 25 seconds		none	0.04	---			

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TABLE 8-9 - TANK VENTING PARAMETERS, SETTLED COAST PHASE

Parameters		Vent Control Pressures*, psia TC-2	TC-3/TC-4** Expected Values	TC-3
LO2 Tank	Did Not Vent During Coast			
Before MES-Tv Seconds	Vent Control Pressure Range, Start	47.0	-	47.0
	Vent Control Pressure Range, Stop	38.0	-	38.0
	Maximum Tank Pressure	32.6	< 47.0	32.12
After MES-Tv Seconds	Vent Control Pressure Range, Start	40.0	-	40.0
	Vent Control Pressure Range, Stop	39.0	-	39.0
	Maximum Tank Pressure	32.61	< 40	32.12
LH_2 Tank	Did Not Vent During Coast			
Before MES-Tv Seconds	Vent Control Pressure Range, Start	28.8	-	28.8
	Vent Control Pressure Range, Stop	27.1	-	27.1
	Maximum Tank Pressure	20.0	< 28.8	19.76
After MES-Tv Seconds	Vent Control Pressure Range, Start	24.5	-	24.5
	Vent Control Pressure Range, Stop	23.5	-	23.5
	Maximum Tank Pressure	20.1	< 24.5	19.76

* Vent enable from MECO #1 + 260 seconds to MES #2 - 97 seconds
** Venting not expected during TC-3 settled coast phase.
(No venting occurred during TC-2 settled coast phase)

Centaur Propellant Feed and Reaction Control Systems

by K. W. Baud

Summary

Performance of the TC-3 Centaur propellant feed and reaction control systems was satisfactory. No anomalies were detected during either the countdown or subsequent launch. Usable peroxide residual at start of the depletion experiment was 203 pounds. Actual time required to deplete the residual peroxide was 1368 seconds versus a predicted time of 1238 seconds. The depletion time difference (130 seconds) was equivalent to 21.3 pounds of peroxide.

Discussion

Propellant Feed System: The ability of the boost pumps to rotate under cryogenic conditions was demonstrated during the countdown by successful completion of the GN_2 spin test at T-45 minutes. Results of the test are presented in Table 8-10 and also compared with previous vehicle testing.

The boost pumps operated normally during both burns. A summary of the performance is presented in Table 8-11. Turbine inlet pressure rise occurred within 2 seconds of the peroxide feed valve opening for both burns. Minor fluctuations in the turbine inlet pressures during the first few seconds of second burn operation indicated a small amount of gas entrainment with the peroxide flow. The liquid hydrogen turbine pressure fluctuated for 7 seconds and the liquid oxygen for 15 seconds. The turbines accelerated smoothly and operated within the expected speed range; corresponding pump headrise was also normal. The LH_2 turbine inlet pressure was slightly lower than expected but was apparently due to instrumentation inaccuracy since the speed and headrise were normal.

Following MECO #2, the LO_2 boost pump accelerated to 55,900 RPM and the LH_2 boost pump accelerated to 54,600 RPM due to the combined effect of pumping cessation and purging of residual peroxide through the turbine catalyst beds. The maximum possible turbine speed predicted by analysis and tests was 68,000 RPM.

A summary of propellant feed system temperature data is presented in Table 8-12. All temperatures were within expected values.

Reaction Control System: Component temperatures were maintained within expected ranges during the prelaunch countdown and flight. A summary of temperatures at selected times is presented in Table 8-13.

Programmed 20 second firings of the S2A, Y1, Y2 and S2B thrusters to prime the peroxide supply lines during the boost phase was verified by the response of thermocouples located on the thrusters. Similarly, the thermocouple response

TABLE 8-10 - CENTAUR BOOST PUMP SPIN-UP TEST DATA

VEHICLE AND TEST		Run Duration	LO2 BOOST PUMP						LH2 BOOST PUMP					
			Rotation Delay	Turbine Inlet Pressure at First Rotation	Turbine Inlet Pressure at Shutdown	Turbine Speed at Shutdown	Pump Headrise at Shutdown	Rotation Coast-down Time	Rotation Delay	Turbine Inlet Pressure at First Rotation	Turbine Inlet Pressure at Shutdown	Turbine Speed at Shutdown	Pump Headrise at Shutdown	Rotation Coast-down Time
Vehicle	units	sec.	sec.	psia	psia	rpm	psid	sec.	sec.	psia	psia	rpm	psid	sec.
AC-32	TCD Spin #1	236	11	57	157	15,900	15.0	35	23	90	156	20,500	4.0	33
	TCD Spin #2	245	14	60	156	15,900	15.0	30	19	69	155	20,500	4.0	35
	Launch	194	14	60	155	16,250	15.0	36	22	78	155	20,600	4.0	29
AC-33	TCD Spin #1	166	17	--	163	14,300	15.1	32	20	--	159	21,450	4.3	31
	TCD Spin #2	160	14	--	162	14,300	15.1	32	25	--	158	21,130	4.3	32
	Launch	190	15	66	156	15,600	15.0	29	20	78	156	20,500	4.3	41
AC-35	TCD	210	17	--	148	14,300	15.0	19	26	--	150	19,825	4.0	32
	Launch	211	16	--	165	16,900	12.0	--	20	--	165	22,100	4.0	--
TC-2	TCD Spin #1	140	14	60	155	15,650	12.6	32	23	87	158	19,800	3.5	31
	TCD Spin #2	204	17	60	160	16,250	13.5	35	20	69	161	20,345	3.4	33
	Abort Spin #1	223	14	54	152	16,575	14.5	38	20	71	148	20,325	4.0	34
	Abort Spin #2	208	16	60	158	16,825	15.7	36	20	70	154	20,450	4.3	31
	Launch	223	13	54	155	16,440	14.4	38	24	81	152	20,460	3.9	34
TC-3	TCD Spin #1	219	24	78	151	14,040	9.3	22	18	63	154	20,020	3.5	39
	TCD Spin #2	212	19	72	161	15,340	12.0	24	13	54	163	21,060	4.0	36
	Launch													
TC-4	TCD Spin #1	217	15	66	155	15,600	Invalid	26	23	75	155	20,475	3.7	31
	Retanking Spin #2	213	17	64	152	15,470	13.2	28	22	77	156	20,670	3.7	28
	Launch	211	19	63	156	15,730	13.5	25	25	78	156	20,475	3.5	27

TABLE 8-11 - CENTAUR BOOST PUMP PERFORMANCE DATA SUMMARY

TC-3

Parameter	Measurement Number	Units	First Burn			Second Burn		
			Prestart	MES	MECO	Prestart	MES	MECO
LO_2 Boost Pump								
Pump Headrise ΔP	CPT 120P	psid	81.8	79.5	30.0	62.3	81.0	30.0
Turbine Speed	CPT 15B	rpm	39,000	39,000	34,970	34,125	40,300	35,100
Turbine Inlet Pressure	CPT 26P	psid	96.0	96.0	96.0	99.0	99.0	99.0
LH_2 Boost Pump								
Pump Headrise ΔP	CPT 121P	psid	23.9	21.7	12.2	15.5	21.0	12.0
Turbine Speed	CPT 16B	rpm	43,875	42,250	41,600	35,750	42,250	41,275
Turbine Inlet Pressure	CPT 28P	psid	91.5	92.4	92.4	91.5	92.1	94.5

TABLE 8-12 - TC-3 CENTAUR PROPELLANT FEED SYSTEM TEMPERATURE DATA

Parameter	Meas. Number	Units	Event and Event Times							
			T-0	BPS-1	MES-1	MECO-1	BPS-2	MES-2	MECO-2	P/L SEP.
Propellant Feed System										
LH2 boost pump inlet	CP32T	DGF	-421.0	-421.3	-421.4	-422.2	-421.4	-422.3	-425.0	-424.9
LO2 boost pump inlet	CP33T	DGF	-282.5	-282.4	-282.1	-283.3	-281.1	-282.9	-286.6	-286.9
C-1 LO2 duct surface	CP55T	DGF	-277.9	-276.5	-276.5	-279.5	-276.5	-277.7	-283.0	-280.7
C-1 LH2 duct surface	CP56T	DGF	-404.0	-413.9	-411.4	-414.6	>-378.1	-403.8	-417.1	-418.0
C-2 LO2 duct surface	CP57T	DGF	-277.0	-277.9	-277.2	-280.7	-279.1	-278.1	-284.4	-283.9
C-2 LH2 duct surface	CP58T	DGF	-398.2	-409.2	-406.9	-409.2	>-378.1	-381.6	-411.8	-415.4
C-1 LO2 pump inlet	CP59T	DGF	-281.4	-280.4	-280.8	-282.9	>-275.0	-281.4	-286.2	-285.7
C-1 LH2 pump inlet	CP60T	DGF	-419.3	-420.2	-419.9	-420.9	>-414.0	-420.4	-423.0	-417.3
C-2 LO2 pump inlet	CP61T	DGF	-281.3	-280.3	-280.8	-282.9	-278.4	-281.3	-286.2	-285.7
C-2 LH2 pump inlet	CP62T	DGF	-419.7	-420.4	-420.0	-421.0	>-413.6	-420.6	-423.2	-423.5
LO2 Boost Pump Turbine										
Rotor lower bearing	CPT36T	DGF	77	72	106	145	213	222	308	363
Gearcase surface (output)	CP176T	DGF	69	65	72	96	169	170	>206	>206
Catalyst bed surface	CP186T	DGF	110	136	>597	>597	569	>597	>597	>597
LH2 Boost Pump Turbine										
Rotor lower bearing	CPT127T	DGF	77	71	93	132	204	212	308	345
Gearcase surface (output)	CP177T	DGF	70	64	75	110	175	177	>217	>217
Catalyst bed surface	CP187T	DGF	93	109	>597	>597	541	>597	>597	>597

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TABLE 8-13 - TC-3 CENTAUR H202 SUPPLY AND REACTION CONTROL SYSTEM TEMPERATURES

Parameters	Meas. Number	Units	Event and Event Times							
			T-0	BPS-1	MES-1	MECO-1	BPS-2	MES-2	MECO-2	P/L-SEP
H202 Bulk										
RCS bottle	CP93T	DGF	90	90	93	90	94	93	92	93
B/P bottle	CP659T	DGF	87	87	83	88	92	91	91	91
Thrust Chamber Surfaces										
Y1	CP148T	DGF	68	654	594	1128	1194	1212	619	1026
Y4	CP149T	DGF	68	68	68	1043	1212	1246	637	1094
P3	CP375T	DGF	59	57	57	959	1060	1043	567	942
P4	CP376T	DGF	68	68	68	976	1178	1212	646	1010
S2A	CP691T	DGF	62	532	497	434	1255	1255	585	497
S4A	CP693T	DGF	64	57	57	57	1279	1279	611	514
S4B	CP836T	DGF	57	68	63	68	1279	1279	628	514
S2B	CP837T	DGF	57	892	723	550	1262	1262	628	532
H202 Lines to Thruster										
Quad 2/3	CP152T	DGF	82	93	94	96	94	93	88	93
Quad 1/4	CP155T	DGF	80	94	94	96	98	98	96	100
Quad 1/2	CP160T	DGF	70	88	85	86	98	96	88	89
H202 Lines to Boost Pumps										
LH2 orifice inlet	CP361T	DGF	77	64	93	127	144	120	149	175
LO2 orifice inlet	CP714T	DGF	72	81	95	111	127	98	116	109
Between feed valves	CP831T	DGF	77	92	83	92	116	92	92	100
LH2 inlet (near tee)	CP833T	DGF	73	76	137	>147	145	135	>147	>147
Other										
Bottle manifold line	CP756T	DGF	80	96	92	96	100	95	96	98
H202 vent line	CP832T	DGF	84	83	83	84	82	82	78	79
BPFV #2 body	CP834T	DGF	79	78	83	94	104	100	100	111

*DATA QUESTIONABLE - POOR ADHESIVE BOND OF PATCH TO LINE SUSPECTED

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verified the programmed 10 second warming firing of all P and Y thrusters prior to MECO #2 and all settling engine operating modes except for the 2 S-on mode during the settled coast. Switching from the 4 S-on mode to the 2 S-on mode at MECO #1 plus 250 seconds was not confirmed due to lack of telemetry coverage.

The DCU computed hydrogen peroxide consumption at the start of the peroxide depletion experiment was 191.5 pounds. The preflight predicted value was 191.1 pounds. A total of 398.5 pounds was loaded for flight of which 4.4 pounds were unusable. Thus, the predicted usable peroxide at start of the depletion experiment was 203 pounds. The predicted time to deplete the residual peroxide was 1238 seconds. Based on the settling engine temperature data, actual depletion time was 1368 seconds. The 130 seconds difference was equivalent to 21.3 pounds of peroxide.

Two instrumentation anomalies were noted. The liquid hydrogen boost pump peroxide feed line temperature measurement (CP 833T) exhibited temperature variations indicative of local environment rather than true line temperature. Excessive bonding adhesive between the temperature patch and the tube most likely caused the anomalous response. The S2A settling engine temperature measurement (CP 691T) also exhibited an abrupt 10 percent decrease of 67.63 minutes after liftoff and another abrupt 2 percent increase 91.2 minutes after liftoff. The CP 691T anomaly has been attributed to signal attenuation due to a low impedance path from the thermocouple wire to the shield.

Environmental Control and Thermodynamics

by R. F. Lacovic and R. A. Corso

Summary

The environmental control system maintained proper thermal conditioning in all compartments and all component temperatures were maintained well within qualification limits during both prelaunch and flight. All of the TC-3 temperature data was very comparable to previous T/C temperature data except for measurement CP833T (LH_2 B/P inlet line) which apparently became disbonded at liftoff.

Discussion

Temperature survey data from liftoff through spacecraft separation are summarized in Tables 8-14 through 8-18 for the Centaur airframe and mechanical systems. Temperature data from other T/C flights are also listed in the tables for comparison. There is good agreement in all of the temperature data except for measurement CP833T (LH_2 B/P inlet line) which behaved like a disbonded thermocouple. All TC-3 equipment and component temperatures remained well within their operational limits and no significant deviations or anomalous behavior was observed.

TABLE 8-14 - CSS AND ISA TEMPERATURE DATA

Measurement No.	Measurement Location	Lifotff Temp. °F TC-4	Lifotff Temp. °F TC-3	Minimum Temp. °F TC-4	Minimum Temp. °F TC-3	Maximum Temp. °F TC-4	Maximum Temp. °F TC-3
CY112	S/C Comp. Amb	53	56	46	17	53	62
CA80T	Stag. Pt.	100	100	100	100	570	561
CA167T	ISA Sta. 2144	75	78	75	78	170	163
CA16[illegible]	ISA Sta. 2159	75	80	75	80	155	147
CA169T	CSS Sta. 2812	85	84	84	84	332	310
CA170T	CSS Sta. 2688	85	85	84	85	241	225
CA192T	CSS Insul. Sta. 2816	50	58	-10	7	50	58
CA193T	CSS Insul. Sta. 2696	50	58	-25	11	50	58
CA198T	CSS Frame Sta. 2422	50	61	50	61	95	117
CA199T	CSS Diaph. Sta. 2242	-55	-34	-85	-72	-35	-25
CA204T	CSS Insul. Sta. 2452	-40	-34	-60	-34	-30	-29
CA205T	CSS Insul. Sta. 2422	-112	-112	-112	-112	-120	-135
CA209T	CSS Insul. Sta. 2279	-340	-342	-350	-342	-275	-270

TABLE 8-15 - SUMMARY COMPARISON OF TEMPERATURE DATA

System	Meas Number	Description	Vehicle	Temperature, °F at Discrete Event Times							
				Liftoff	Shroud Jettison	MES-1	T+740 Seconds	T+1000 Seconds	T+1500 Seconds	MES-2	S/C Separate
Airframe & Insulation	CA900T	Viking Transition Adapter	TC-1	54	44	43	43	—	—	—	—
			-2	NA	NA	NA	NA	NA	NA	NA	NA
			-3	63	55	53	50		36	31	23
			-4	63	53	53	47	40	30	29	21
	CA914T	Equip. Module Skin, +Z	TC-1	48	35	33	35	—	—	—	—
			-2	52	41	36	35	32	27	26	30
			-3	47	38	38	85	—	85	85	25
			-4	51	45	43	40	39	34	34	27
	CA963T	LH_2 Tank Radiation Shield 2279/03	TC-1	-361	-410	-91	38	—	—	—	—
			-2	-352	-403	-279	-175	-149	-120	-78	-59
			-3	-367	-403	-64	29	—	40	-41	-116
			-4	-354	-408	-165	-100	-85	-100	-100	-120
Component and Payload Compartment	CY112T	Spacecraft Comp. Ambient	TC-1	53	36	75	130	—	—	—	—
			-2	NA	NA	NA	NA	NA	NA	NA	NA
			-3	62	50	62	63	—	43	39	25
			-4	53	46	51	47	32	21	20	10
	CE756T	RSC Battery #1 Internal	TC-1	83	80	76	76	—	—	—	—
			-2	108	79	78	76	74	70	67	66
			-3	106	94	94	89	—	83	82	78
			-4	92	87	84	83	81	79	78	70
	CE757T	RSC Battery #2 Internal	TC-1	97	90	87	87	—	—	—	—
			-2	79	88	97	90	97	93	95	96
			-3	82	79	75	76	—	69	71	73
			-4	84	90	77	77	76	73	73	68
	CI300T	IRU Skin Internal	TC-1	80	80	86	86	—	—	—	—
			-2	77	84	85	85	66	85	85	85
			-3	76	78	78	87	—	91	91	93
			-4	77	78	78	80	82	83	83	81
	CK 30T	DCU Skin	TC-1	77	80	[illegible]	87	—	—	—	—
			-2	87	92	90	94	96	97	102	106
			-3	80	82	80	87	—	93	95	97
			-4	82	85	86	88	90	95	96	97
Centaur Hydraulics	CH 5T	C-1 Hydraulic Manifold	TC-1	68	65	60	56	—	—	—	—
			-2	70	63	65	71	73	76	76	79
			-3	77	69	69	98	—	90	87	145
			-4	66	62	62	96	—	86	82	152
	CH 6T	C-2 Hydraulic Manifold	TC-1	70	63	60	56	—	—	—	—
			-2	49	60	45	59	61	67	71	73
			-3	60	60	71	94	—	87	87	145
			-4	47	47	47	94	—	86	82	145
Centaur Pneumatics	CF 4T	Helium Storage Bottle	TC-1	81	79	67	64	—	—	—	—
			-2	78	77	64	66	65	65	37	49
			-3	82	82	60	66	—	66	21	30
			-4	83	82	52	64	[illegible]	55	4	20
	CF134T	Aft Pneumatic Panel #2	TC-1	66	61	56	43	—	—	—	—
			-2	61	48	47	54	43	36	33	31
			-3	69	56	56	66	—	115	96	69
			-4	68	54	53	71	76	35	54	41

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TABLE 8-16 - SUMMARY COMPARISON OF TEMPERATURE DATA

System	Meas Number	Description	Vehicle	Temperature, °F at Discrete Event Times: Liftoff	Shroud Jettison	MES-1	T+740 Seconds	T+1000 Seconds	T+1500 Seconds	MES-2	S/C Separate
H_2O_2 Supply System (continued)	CP832T	H_2O_2 Vent Line No. 1	TC-1	85	86	84	84	—	—	—	—
			-2	82	87	87	87	88	90	91	88
			-3	82	82	82	94		82	82	78
			-4	80	90	84	84	—	84	84	80
	CP833T	LH_2 BP Inlet Line	TC-1	91	70	82	131	—	—	—	—
			-2	84	68	73	121	123	101	98	151
			-3	76	57	137	OSH		OSH	135	OSH
			-4	88	66	92	117	—	120	98	117
	CP834T	BP Feed Valve #2 Body	TC-1	73	75	84	87	—	—	—	—
			-2	72	77	81	90	93	93	92	98
			-3	78	78	87	95		101	99	109
			-4	79	77	90	94	—	103	100	107
Centaur Main Propulsion System	CP118T	C-1 Engine Fuel Pump BU	TC-1	-380	-295	-380	-409	—	—	—	—
			-2	-384	-285	-350	-335	-295	-257	-442	-363
			-3	-386	-293	-267					-322
			-4	-392	-290	-350	-325	—	-252	-362	-350
	CP119T	C-2 Engine Fuel Pump BU	TC-1	-380	-290	-380	-407	—	—	—	—
			-2	-382	-290	-362	-338	-317	-275	-443	-320
			-3	-388	-300	-274					-325
			-4	-379	-290	-357	-325	—	-250	-358	-350
	CP122T	C-1 Engine Fuel Pump	TC-1	-380	-295	-380	-414	—	—	—	—
			-2	-388	-285	-350	-338	-296	-258	-414	-409
			-3	-396	-293	-273				—	-322
			-4	-402	-290	-350	-325	—	-252	-360	-350
	CP123T	C-2 Engine Fuel Pump	TC-1	-380	-290	-380	-407	—	—	—	—
			-2	-383	-285	-350	-338	-300	-262	-409	-407
			-3	-386	-298	-277				-274	-322
			-4	-385	-290	-358	-325	—	-250	-360	-352
	CP124T	C-1 Engine LO_2 Pump	TC-1	-57	-77	-94	-127	—	—	—	—
			-2	-66	-90	-175	-220	-202	-173	-144	-272
			-3	-51	-71	-94				-190	-252
			-4	-60	-74	-100	-240	—	-144	-138	-270
	CP125T	C-2 Engine LO_2 Pump	TC-1	-48	-69	-90	-123	—	—	—	—
			-2	-51	-80	-170	-222	-204	-134	-99	-258
			-3	-40	-58	-84				-115	-190
			-4	-60	-72	-208	-212	—	-108	-100	-224
	CP144T	C-2 Engine Compartment Amb.	TC-1	68	68	-135	-275	—	—	—	—
			-2	60	40	-11	-11	-11	-22	-199	-33
			-3	69	40	-66	22		-133	-165	-2
			-4	70	46	46	22	17	-27	-199	-44
	CP828T	C-2 Engine Turbopump Surf.	TC-1	-293	-300	-288	—	—	—	—	—
			-2	-371	-299	-310	-318	-304	-263	-231	-347
			-3	-381	-304	-331	-347		-238	-351	-322
			-4	-388	-305	-267	-340	—	-248	-246	-340
	CP829T	C-2 Engine Pump Shield	TC-1	-27	-250	-27	—	—	—	—	—
			-2	9	-215	-44	-125	-150	-113	-78	-113
			-3	29	-188	-101	-155		-106	-135	OSL
			-4	-20	-200	-80	-200	—	-135	-130	OSL

TABLE 8-17 - SUMMARY COMPARISON OF TEMPERATURE DATA

System	Meas Number	Description	Vehicle	Temperature, °F at Discrete Event Times: Liftoff	Shroud Jettison	MES-1	T-730 Seconds	T-1000 Seconds	T-1[illegible]00 Seconds	MES-2	S-C Separate
Centaur Propellant Feed System	CP127T	LH_2 BP Turbine Bearing	TC-1	75	72	70	145	—	—	—	—
			-2	[illegible]2	70	97	153	169	186	202	298
			-3	76	76	9[illegible]	165		207	205	343
			-4	77	73	9[illegible]	170	—	203	210	362
	CP186T	LO_2 BP Decomp. Chamber	TC-1	NA	NA	NA	NA	NA	NA	NA	NA
			-2	110	120	>597	>597	>597	>597	>597	>597
			-3	113	12[illegible]	[illegible]597	>597		>597	>597	>597
			-4	110	120	>597	>597	—	>597	>597	>597
	CP187T	LH_2 BP Decomp. Chamber	TC-1	NA	NA	NA	NA	NA	NA	NA	NA
			-2	100	110	>597	>597	>597	>597	>597	>597
			-3	102	102	>597	>597		579	>597	>597
			-4	101	107	>597	>597	>597	>597	>597	>597
	CP361T	LH_2 BP Supply Line Near Orifice	TC-1	79	60	105	136	—	—	—	—
			-2	77	63	100	134	134	116	116	183
			-3	82	56	102	164		149	119	175
			-4	76	57	101	158	—	127	103	171
	CP714T	LO_2 BP Inlet Line	TC-1	66	40	95	102	—	—	—	—
			-2	66	40	96	99	117	111	111	106
			-3	71	46	99	105		130	97	108
			-4	66	47	96	110	—	131	99	105
Centaur H_2O_2 Supply System	CP 93T	Attitude Control H_2O_2 Bottle	TC-1	84	83	83	83	—	—	—	—
			-2	85	84	85	87	87	87	87	88
			-3	86	84	86	86		88	91	68
			-4	86	86	89	89	—	90	90	90
	CP152T	Quad 2/3 A/C Line	TC-1	80	80	92	94	—	—	—	—
			-2	72	70	92	91	90	89	90	94
			-3	82	78	92	95		95	95	93
			-4	82	76	95	96	—	96	94	88
	CP155T	Quad 1/4 A/C Line	TC-1	77	78	92	96	—	—	—	—
			-2	70	71	95	94	95	95	95	96
			-3	75	75	94	97		99	98	99
			-4	74	72	92	96	—	96	96	96
	CP160T	Quad 1/2 A/C Line	TC-1	NA	NA	NA	NA	NA	NA	NA	NA
			-2	NA	NA	NA	NA	NA	NA	NA	NA
			-3	69	59	84	95		97	98	99
			-4	72	64	85	94	—	94	92	84
	CP659T	Boost Pump H_2O_2 Bottle	TC-1	82	82	82	82	—	—	—	—
			-2	80	80	82	83	84	86	87	88
			-3	85	85	85	65		86	88	86
			-4	83	83	83	85	—	88	88	86
	CP756T	H_2O_2 Crossover Line	TC-1	83	83	92	92	—	—	—	—
			-2	88	90	88	93	93	93	93	94
			-3	78	87	91	99		99	100	93
			-4	78	93	94	96	—	99	96	97
	CP831T	Line Btwn. BP Feed Valves	TC-1	82	92	84	95	—	—	—	—
			-2	83	96	91	93	107	119	111	97
			-3	82	84	93	97		129	91	99
			-4	80	86	95	101	—	123	96	103

TABLE 8-18 - SUMMARY COMPARISON OF TEMPERATURE DATA

System	Meas Number	Description	Vehicle	Temperature, °F at Discrete Event Times							
				Liftoff	Shroud Jettison	MES-1	T+740 Seconds	T+1000 Seconds	T+1500 Seconds	MES-2	S.C Separate
Centaur H_2O_2 Propulsion System	CP148T	Y1 Chamber Surface	TC-1	80	70		—	—	—	—	—
			-2	89	69	600	991	942	963	1070	1105
			-3	69	89	620	1160		1129	1211	959
			-4	68	68	567	1128	—	1110	1110	969
	CP149T	Y4 Chamber Surface	TC-1	75	60	75	—	—	—	—	—
			-2	79	50	60	992	1112	863	1150	1182
			-3	69	50	69	891		1009	1245	1076
			-4	68	45	45	841	—	1043	1144	1026
	CP375T	P3 Chamber Surface	TC-1	70	60	70	—	—	—	—	—
			-2	79	60	64	1133	1119	663	1006	635
			-3	79	79	79	1009		1076	1043	942
			-4	45	45	45	976	—	1043	959	807
	CP376T	P4 Chamber Surface	TC-1	70	60	75	—	—	—	—	—
			-2	79	60	69	820	800	742	1384	1077
			-3	79	79	79	1128		1143	1194	1009
			-4	57	34	45	1110	—	1144	1161	1026
	CP691T	S2A Chamber Surface	TC-1	75	65		—	—	—	—	—
			-2	75	68		1250	1260	580	1260	570
			-3	69	69	505	1228		636	1262	496
			-4	69	57	514	1086	—	1110	1110	470
	CP693T	S4A Chamber Surface	TC-1	70	65	72	—	—	—	—	—
			-2	79	69	69	1252	1270	600	1259	620
			-3	69	69	67	1245		514	1279	671
			-4	57	45	45	1211	—	1212	1212	470
	CP836T	S4B Chamber Surface	TC-1	65	60	70	—	—	—	—	—
			-2	75	65	75	1295	580	1290	1290	650
			-3	69	50	69	1279		1279	1279	514
			-4	57	45	57	1077	—	1103	1103	470
	CP837T	S2B Chamber Surface	TC-1	70	60		—	—	—	—	—
			-2	70	60		1230	550	1220	1220	630
			-3	69	50	734	1245		1245	1262	514
			-4	57	45	714	1178	—	1178	1178	443
	CPT36T	LO_2 BP Turbine Bearing	TC-1	66	64	68	—	—	—	—	—
			-2	72	71	97	152	173	197	216	320
			-3	73	73	105	165		207	225	361
			-4	77	74	103	162	180	205	213	259
	CP176T	LO_2 BP Gearcase	TC-1	NA	NA	NA	NA	NA	NA	NA	NA
			-2	66	63	72	115	174	160	177	—
			-3	77	66	75	110		162	170	>206
			-4	64	64	72	119	—	165	168	>206
	CP177T	LH_2 BP Gearcase	TC-1	NA	NA	NA	NA	NA	NA	NA	NA
			-2	61	58	61	114	130	148	157	217
			-3	72	66	77	128		170	178	>217
			-4	70	64	74	134	—	173	174	>217

Electrical/Electronic Systems

Electrical Power System

by W. W. Hultzman

Configuration: The electrical power system, Figure 8-7, consists of a power changeoever switch (integral part of the Sequence Control Unit), a main battery, two independent Range safety command (vehicle destruct) batteries, and a single phase, 400 hertz inverter (inverter is an integral part of the Servo-Inverter Unit).

System Performance: Transfer of the Centaur electrical loads from external power to the internal battery by the changeover switch occurred at minus 113.8 seconds. The Centaur electrical system satisfactorily supplied power throughout the countdown and flight until loss of telemetry data at 6961 seconds.

However, a current anomaly similar to that on TC-4 was observed. An unexpected main battery current demand of 3.2 amperes was observed on measurement CEIC upon data acquisition from the Ascension station at 1360 seconds (latter part of first coast phase). This additional load gradually increased to a maximum of 6 amps at about 1500 seconds, then decreased to about 2 amps by 1567 seconds. Random, low frequency fluctuations of less than 2 amps occurred through the MES 2 sequence at 1706 seconds. No further abnormal load demands occurred until 3930 seconds, or after the propellant tank blowdown sequence (3408 seconds). After this time, low frequency random current increases averaged about 3 amps, with peaks up to 8.5 amps, until loss of data at 6961 seconds. As on TC-4, the unexpected current demands were observed as a slight main battery voltage decrease. However, the abnormal current load was not observed on the individual bus or package currents.

As described for the TC-4 flight, the abnormal current demand was attributed to electrolyte leakage from one or more battery cells to the battery case through the shortened fill/vent valve. This occurred in the zero-g flight environment during the coast phases of flight. TC-3 and TC-4 were the first flights to use this valve configuration for 150 ampere-hour batteries. The fill/vent valves will be lengthened and changed to nylon for subsequent flights.

Main battery current was 38.5 amperes at liftoff, peaking at 57.0 amps at MES 1 and 59.3 amperes at MES 2. The flight current profile, as well as individual bus and component currents were normal and consistent with preflight test data, except for the previously discussed current anomaly. Battery current values with respect to flight-programmed events are shown in Table 8-19.

The main battery voltage was 27.4 volts at liftoff (Table 8-20). A minimum value of 26.2 volts was indicated during the MES 1 sequence, and 26.9 volts at MES 2. The voltage recovered to 28.0 volts at spacecraft separation, gradually increasing to a maximum of 28.3 volts at loss of data at 6961 seconds (Table 8-21).

FIGURE 8-7 - TC-3/4 SINGLE BATTERY CONFIGURATION

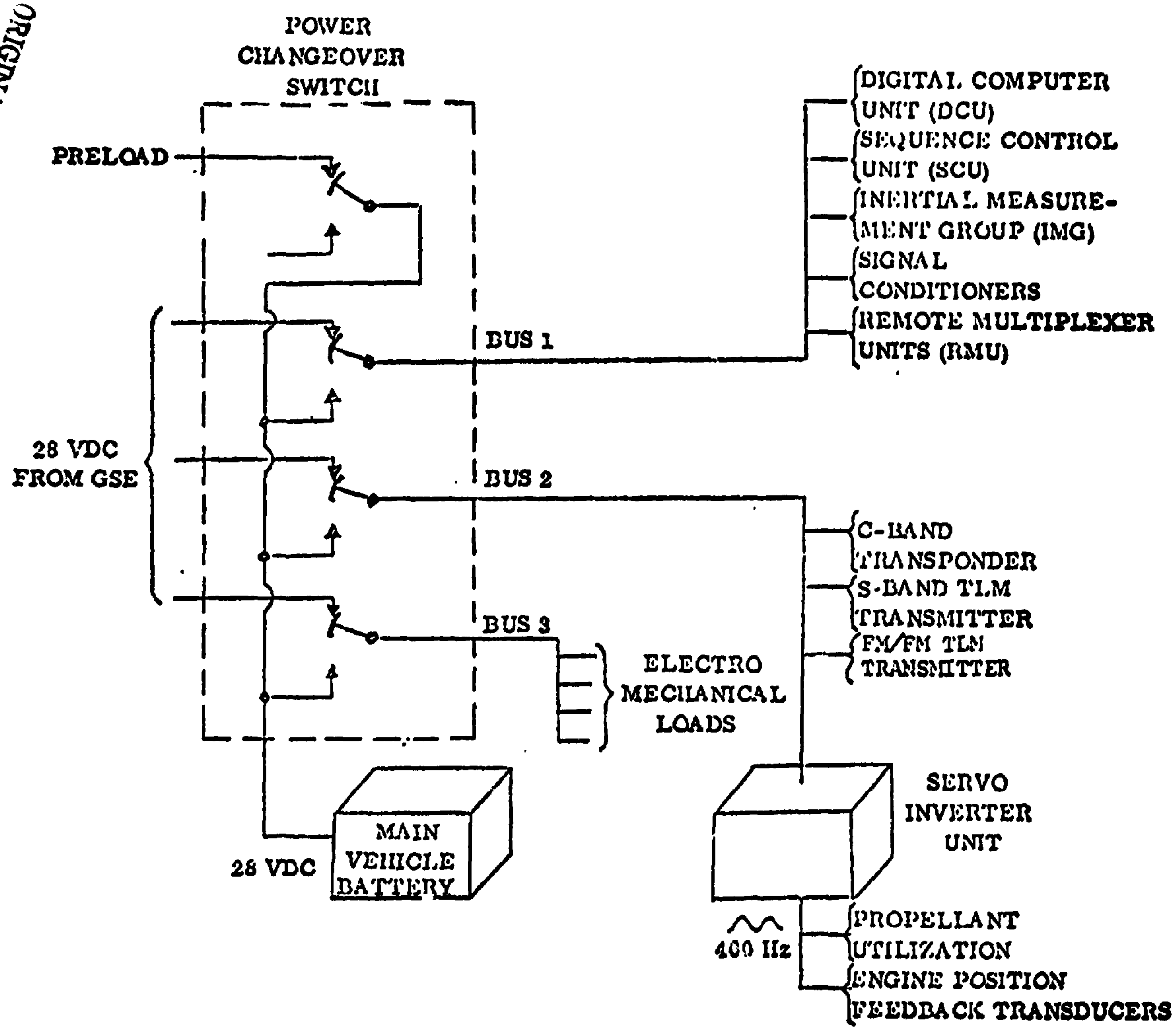

TABLE 8-19 - TC-3 CENTAUR BATTERY CURRENT PROFILE

	CALCULATED		ACTUAL	TIME
	NOMINAL	MAXIMUM		SECONDS
Centaur to Internal	39.0	58.3	36.0	-113.8
Lock LH2 Vent Valve	40.2	62.3	38.0	- 27.8
Liftoff (T-0)	40.5	62.6	38.5	0
Unlock LH2 Vent Valve	38.8	58.1	36.7	90.0
Separate Fwd. Bearing Reactor	39.0	58.5	37.0	100.0
Reset Fwd. Bearing Reactor	38.8	58.1	36.7	102.0
Forward Seal Release	39.0	58.5	37.0	211.2
Reset Fwd. Seal Release	38.8	58.1	36.7	214.3
Shroud Coax Switches	37.8	56.1	36.0	272.0
H2O2 Engines - S2A On	38.3	56.7	36.5	276.6
H2O2 Engines - S2A Off; Y1 On	38.3	56.7	36.5	296.6
H2O2 Engines - Y1 Off; Y2 On	38.3	56.7	36.5	316.6
H2O2 Engines - Y2 Off	37.8	56.1	36.0	336.6
H2O2 Engines - S2B On	38.3	56.7	36.5	379.6
H2O2 Engines - S2B Off	37.8	56.1	36.0	399.6
Lock All Vent Valves	41.2	66.3	40.5	437.1
LO2 & LH2 Tank Pressurization; Control Valve On	43.6	75.3	43.0	439.1
Boost Pumps - Primary & Backup On; H2O2 Purge Valve On	46.7	79.2	45.3	439.2
End LO2 & LH2 Pressurization	45.9	76.2	44.0	440.7
Hydraulic Circ. Pumps On	52.1	92.3	48.5	469.4
Open Prestart Valves	54.9	95.6	51.7	475.6
Control Valve Off	54.1	92.6	50.5	483.5
MES 1: Igniters On: Open Start Valves	60.3	96.7	57.0	483.7
Igniters Off	56.8	91.7	53.5	487.7
Hydraulic Circ. Pumps Off	51.4	78.7	48.5	495.7
H2O2 Engines - Y's & P's On	55.4	83.1	50.5	593.2
H2O2 Engines - Y's & P's Off	51.4	78.7	47.5	603.0
MECO 1: Boost Pumps Primary & Backup Off: H2O2 Purge Valve Off; Close Start & Prestart Valves	42.7	68.0	39.0	613.0

TABLE 8-19 - TC-3 CENTAUR BATTERY CURRENT PROFILE (CONTINUED)

	CALCULATED			TIME
	NOMINAL	MAXIMUM	ACTUAL	SECONDS
H202 Engines - All "S On" Mode	44.7	70.2	41.0	613.1
H202 Engines - "S-1/2 On" Mode	43.7	69.1	(1)	(1)
H202 Engines - All "S" On Mode	44.7	70.2	(1)	(1)
Hydraulic Circ. Pumps On	50.1	83.2	(1)	(1)
LO2 & LH2 Tank Pressurization & Control Valve On	52.5	92.2	(1)	(1)
Boost Pumps - Primary & Backup On: H202 Purge Valve On	55.6	96.1	50.5	1677.6
Open Prestart Valves	58.4	99.5	53.5	1688.5
End LO2 & LH2 Tank Pressurization; Control Valve Off	56.0	90.5	52.7	1705.3
MES 2: Igniters On; Open Start Valves: Y & P H202 Engines Off	98.9	62.3	59.3	1705.6
Igniters Off	58.8	93.9	54.5	1709.6
H202 4S Engines Off	56.8	91.7	52.5	1710.6
Hydraulic Circ. Pumps Off	51.4	78.7	48.0	1717.6
MECO 2: Boost Pumps Primary & Backup Off; H202 Purge Valve Off; Close Start & Prestart Valves	42.7	68.0	40.0	2007.6
Control Valve On; LO2 Tank Pressurization On	45.1	77.0	41.6	2017.6
LO2 Tank Pressurization Off	44.3	74.0	40.6	2026.3
Control Valve Off	42.7	68.0	40.0	2217.5
Separate Viking Command	42.9	68.4	40.3	2227.6
Separate Viking Command Reset	42.7	68.0	40.0	2232.6
H202 Engines - 4S On Mode	44.7	70.2	(1)	(1)
H202 Engines Off	42.7	68.0	(1)	(1)
Hydraulic Circ. Pumps On	48.1	81.0	44.0	3057.6
Open Prestart Valves	50.9	84.4	46.7	3082.8
Hydraulic Circ. Pumps Off; Close Prestart Valve	42.7	68.0	39.7	3332.8
H202 Engines - 4S On Mode	44.7	70.2	41.3	3337.8
Unlock All Vent Valves	41.3	60.0	37.6	3407.8
H202 Engines - 4S Engines Off	39.3	57.8	38.3	5337.8

(1) Loss of Telemetry Data

TABLE 8-20 - TC-3 CENTAUR BATTERY DATA

	OPEN CIRCUIT	T-0 LIFTOFF	LOAD TEST
Main Battery Voltage	34.9	27.4	27.2 @ 65A
RSC No. 1 Battery Voltage	34.3	33.0	28.93 @ 10A
RSC No. 2 Battery Voltage	34.3	32.9	29.06 @ 10A

TABLE 8-21 - TC-3 - CENTAUR ELECTRICAL SYSTEM PARAMETERS

MEAS. NO.	DESCRIPTION	UNITS	T-0	SHROUD SEP.	T/C SEP.	MES NO. 1	MECO NO. 1	MES NO. 2	MECO No. 2	S/C SEP.	START BLOW DOWN
CE1C	Main Battery Current	Amps	38.5	36.0	40.3	57.0	39.0	59.3	40.0	40.3	46.7
CE600V*	Main Battery Voltage	VDC	27.4	27.3	26.7	26.2	27.2	26.9	27.9	28.0	28.1
CE28V	Bus No. 1 Voltage	VDC	27.2	27.1	26.7	26.1	27.2	27.1	27.8	28.0	28.0
CE142C	Bus No. 1 Current	Amps	9.6	9.9	9.9	9.9	9.9	9.9	9.9	9.6	9.9
CE143C	Bus No. 2 Current	Amps	8.4	8.4	8.4	8.4	8.4	8.4	8.5	8.2	8.0
CE144C	Bus No. 3 Current	Amps	11.9	10.2	16.9	21.9	14.3	20.8	14.0	14.0	16.6
CE97C	Bus No. 3 Partial Curr.	Amps	0.8	0	0.8	1.8	0	1.0	0	0.2	0
CS844V	Inverter Output Volts	VAC	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9
CE21V*	RSC Battery No. 1	VDC	33.0	33.1	33.1	33.1	33.1	33.7	33.7	33.7	33.7
CE22V*	RSC Battery No. 2	VDC	32.9	32.9	32.9	32.9	32.9	33.8	33.8	33.8	33.8

*Corrected to Panel Meter Reading at T-10 Seconds

As for TC-4, the Range safety command batteries remained stable during flight. At liftoff battery voltages were 33.0 and 32.9 volts, respectively, remaining steady until RF disable after MECO 1.

The Servo-Inverter Unit supplied AC power at a constant 25.9 volts throughout the programmed flight.

Several interim modifications were made to the B600P/J9 staging disconnect on TC-3 and TC-4. These changes resulted from the loss of telemetry data on AC-32 after insulation panel jettison and prior to staging.

Modifications included machining of the connector plug shell to increase contact engagement by 0.050 inch, shock-mounting the receptacle plate with grommets and shimming the "birdcage" to reduce shock and remove any harness prestress. Wires on the "birdcage" side of the receptacle were potted to minimize wire breakage, and a wiggle test was added to check continuity on the receptacle (pin) side.

Digital Computer Unit

by D. S. Repas

Performance of the DCU throughout the flight for TC-3 was satisfactory as evidenced by proper functioning of flight events and operation of associated systems. The data indicating DCU performance are presented with the flight performance analyses of the associated systems.

Inertial Measurement Group

by P. W. Kuebeler

The Inertial Measurement Group (IMG) performance during the flight of TC-3 was satisfactory as evidenced by the accuracy of the trajectory, which is described in the Trajectory and Performance Section, and the telemetered data which is considered below.

The IMG consisted of IRU S/N 13, P/N GG80654A4 and SEU S/N 24, P/N EG8076B1. Gimbal loop performance was satisfactory. The maximum gimbal error observed was approximately 11 arcseconds as compared to a specification of 60 arcseconds. IMG current was normal throughout the flight. The IRU temperature was 76°F at liftoff and rose to 91°F by the end of the flight. These temperatures were well within the operating range of the IRU.

Flight Control System

The Digital Computer Unit (DCU) and the Sequence Control Unit (SCU) performed satisfactorily in issuing the flight control system commands to other vehicle systems during the flight of TC-3. The SCU receives its input from the DCU and converts this input into switch commands usable by other vehicle systems. The DCU commands were issued at the expected times and for the expected duration of time.

Table 8-22 lists the planned switching sequence and actual flight events. The column headed "Sequence" shows the time of the event from the start of each phase of flight. The column headed "Planned Time" shows the time after liftoff for each event based upon preflight actual launch time trajectory with launch day winds. The "Actual Time" column shows the time after liftoff that the DCU command was issued to the SCU. Other functions programmed by the DCU software are shown in the table to help in clarifying the flight sequence.

TABLE 8-22 - TC-3 FLIGHT SEQUENCE OF EVENTS

SCU	SWITCH	EVENT	SEQUENCE	PLANNED TIME-SEC	ACTUAL TIME-SEC
84 85 86	Reset Reset Reset	Go Inertial (1)	T-6.0	T-6.0	T-6.0
-	-	Liftoff (2)	0.0	0.0	0.0
57,58	Set	Begin Roll Program	SRM+6.5	6.5	6.6
57,58	Reset	End Roll Program	(3)	6.9	6.9
-	-	(4)Begin DCU Pitch, Yaw Program	SRM+10.0	10.0	10.1
28	Reset	Unlock LH_2 Vent Valve 1	SRM+90.0	90.0	90.0
34	Set	Sep Fwd Brg Reactor	SRM+100.0	100.0	100.0
34	Reset	Reset Fwd Brg Reactor	SRM+102.0	102.0	102.0
-	-	(5)STG 0 Shutdown detected by DCU	STG0+0	(6)110.0	111.0
-	-	End Pitch, Yaw Program	STG0+0	(6)110.0	111.0
-	-	Enable Titan Steering	STG0+32	142.0	143.0
39	Set	Release Fwd Seal	STG0+100	210.0	211.0
39	Reset	Reset Fwd Seal	STG0+103	213.0	214.0
-	-	Inhibit Titan Steering	STG0+122	232.0	233.0
-	-	(7)STG 1 Shutdown detected by DCU	STG1+0	(6)258.0	261.6
61	Set	Unlatch Shroud CMD 1	STG1+10	268.0	271.6
62	Set	Unlatch Shroud Cmd 2	STG1+10.5	268.5	272.1

(1) Go inertial occurs 25 seconds after the control monitor group sends a command to start the DCU count.
(2) Liftoff-Defined as start of Rocket Motor Ignition (DRS 496) 14:38:59.960 EDT.
(3) End roll program-Time is launch azimuth dependent.
(4) Pitch Yaw Steering-enabled when altitude exceeds 1050 feet and time exceeds 10 seconds from SRM ignition.
(5) STG 0 shutdown-noted by DCU when computing a decreasing acceleration of less than 1.5g's.
(6) Expected time from preflight actual launch time trajectory, dated 12 September 1975.
(7) STG 1 shutdown-noted by DCU when computing a decreasing acceleration of less than 1.5g's.

TABLE 8-22 - TC-3 FLIGHT SEQUENCE OF EVENTS (CONTINUED)

SCU	SWITCH	EVENT	SEQUENCE	PLANNED TIME-SEC	ACTUAL TIME-SEC
61	Reset	Reset Shroud CMD 1	STG1+11.5	269.5	273.1
62	Reset	Reset Shroud CMD 2	STG1+11.5	269.5	273.1
8	Set	S2A On	STG1+15.0	273.0	276.6
8	Reset	S2A Off	STG1+35.0	293.0	296.6
1	Set	Y1 On	STG1+35.0	293.0	296.6
-	-	Enable Titan Steering	STG1+35.0	293.0	296.6
1	Reset	Y1 Off	STG1+55.0	313.0	316.6
2	Set	Y2 On	STG1+55.0	313.0	316.6
2	Reset	Y2 Off	STG1+75.0	333.0	336.6
12	Set	S2B On	STG1+118.0	376.0	379.6
12	Reset	S2B Off	STG1+138.0	396.0	399.6
24	Set	Lock LO_2 Vent Valve	STG2-30.5	433.5	437.1
28	Set	Lock LH_2 Vent Valve 1	STG2-30.5	433.5	437.1
31	Set	Lock LH_2 Vent Valve 2	STG2-30.5	433.5	437.1
-	-	Inhibit Titan Steering	STG2-30.0	434.0	437.6
27	Set	Open Control Valve	STG2-28.56	435.0	439.1
29	Set	Press LO_2 Tank	STG2-28.56	435.0	439.1
32	Set	Press LH_2 Tank	STG2-28.56	435.0	439.1
23.	Set	Primary Boost Pumps On	STG2-28.4	435.6	439.2
18	Set	B/U Boost Pumps On	STG2-28.4	435.6	439.2
-	-	(8)<u>STG 2 Shutdown detected by DCU</u>	STG2+0	(6)464.0	469.4
65	Set	STG2 S/D B/U	STG2+0	(6)464.0	469.4
17	Set	C1 Circ Pump On	STG2+.1	464.1	469.5
21	Set	C2 Circ Pump On	STG 2+.1	464.1	469.5
63	Set	(9)<u>T/C Separation</u>	SEP+0	(6)470.0	473.2
64	Set				
19	Set	Open Prestart Valves	SEP+2.5	472.5	475.7
27	Reset	Close Control Valve	SEP+10.22	480.0	483.5

(8) Stage II shutdown - noted by DCU when observed acceleration is less than 1g.
(9) T/C separation - commanded by DCU when computed acceleration is less than 0.01g.
(6) Expected time from preflight actual launch time trajectory, dated 12 September 1975.

TABLE 8-22 - TC-3 FLIGHT SEQUENCE OF EVENTS (CONTINUED)

SCU	SWITCH	EVENT	SEQUENCE	PLANNED TIME-SEC	ACTUAL TIME-SEC
-	-	(10) MES I	SEP+10.5	(6)480.5	483.7
22	Set	Igniters On	SEP+10.5	(6)480.5	483.7
20	Set	Open Start Valves	SEP+10.5	(6)480.5	483.7
22	Reset	Igniters Off	MESI+4	484.5	487.7
-	-	Start Guidance Steering	MESI+7	487.5	490.7
17	Reset	C1 Circ Pump Off	MESI+12	492.5	495.7
21	Reset	C2 Circ Pump Off	MESI+12	492.5	495.7
1-4	Set	Yaw Engines On	(13)MECOI-20	588.6	593.2
5,6	Set	Pitch Engines On			
15,16	Set				
1-4	Reset	Yaw Engines Off	MECOI-10	598.6	603.1
5,6	Reset	Pitch Engines Off	MECOI-10	598.6	603.1
15,16	Reset				
-	-	(11)MECO I	MECOI+0	608.6	613.1
23	Reset	Primary-Boost Pumps Off	"	"	"
18	Reset	B/U Boost Pumps Off	"	"	"
20	Reset	Close Start Valves	"	"	"
[illegible]	Reset	Close Prestart Valves	MECOI+0	508.6	613.1
8	Set	Settling Engines On	MECOI+.1	608.7	613.2
10	Set	"	"	"	"
12	Set	"	"	"	"
14	Set	Settling Engines On	MECOI+.1	608.7	613.2
68,72	Reset	Reset PU Switches	MECOI+1.0	609.6	614.1
76,80					
-	-	Reduce to 2S Engines On	MECOI+250	858.6	(12)
12,14	Reset	S2B, S4B Off			
-	-	Change S Engine Pairs	(Halfway thru 2S On Mode)	1224.4	(12)
8,10	Reset	S2A, S4A Off			
12,14	Set	S2B, S4B On			

(10) MES I - commanded by the DCU 10.5 seconds after T/C separation.
(11) MECO I - commanded by the DCU based on guidance computed time.
(12) No telemetry recovered.
(13) MECO I-20 - MECO time used here is the guidance predicted time at that particular instant.
(6) Expected time from preflight actual launch time trajectory, dated 9/12/75.

TABLE 8-22 - TC-3 FLIGHT SEQUENCE OF EVENTS (CONTINUED)

SCU	SWITCH	EVENT	SEQUENCE	PLANNED TIME-SEC	ACTUAL TIME-SEC
-	-	Increase to 4S Engines On	MESII-120	1578.4	1585.7
8,10	Set	S2A, S4A On			
17	Set	C1 Circ Pump On	MESII-60	1638.4	(12)
21	Set	C2 Circ Pump On	MESII-60	1638.4	(12)
27	Set	Open Control Valve	MESII-38.06	1660.3	(12)
29	Set	Press LO_2 Tank	MESII-38.06	1660.3	(12)
32	Set	Press LH_2 Tank	MESII-38.06	1660.3	(12)
23	Set	Primary Boost Pumps On	MESII-28.0	1670.4	1677.7
18	Set	B/U-Boost Pumps On			
19	Set	Open Prestart Valves	MESII-17	1681.4	1688.7
-	-	End Pressurization Enable	MESII-0.28	1698.1	1705.5
-	-	(14) MES II	MESII+0	(6)1698.4	1705.7
20	Set	Open Start Valves	MESII+0	(6)1698.4	1705.7
22	Set	Igniters On	MESII+0	(6)1698.4	1705.7
1-4	Reset	Yaw Engines Off	MESII+.2	1698.6	1705.9
5,6	Reset	Pitch Engines Off	MESII+.2	1698.6	1705.9
15,16	Reset				
22	Reset	Igniters Off	MESII+4	1702.4	1709.7
8	Reset	End 4S Settled Thrust	MESII+5	1703.4	1710.8
10	Reset				
12	Reset				
14	Reset				
-	-	Start Guidance Steering	MESII+7	1705.4	1712.7
17	Reset	C1 Circ Pump Off	MESII+12	1710.4	1717.7
21	Reset	C2 Circ Pumps Off	MESII+12	1710.4	1717.7

(14) MES II- Commanded by the DCU based on guidance computed time.
(12) No telemetry recovered
(6) Expected time from preflight actual launch time trajectory, dated 12 September 1975.

TABLE 8-22 - TC-3 FLIGHT SEQUENCE OF EVENTS (CONTINUED)

SCU	SWITCH	EVENT	SEQUENCE	PLANNED TIME-SEC	ACTUAL TIME-SEC
-	-	(15) MECO II	MECOII+0	(6)2004.8	2007.7
23	Reset	Primary Boost Pumps Off	"	"	"
19	Reset	Close Prestart Valves	"	"	"
20	Reset	Close Start Valves	"	"	"
18	Reset	B/U Boost Pumps Off	"	"	"
68,72 76,80	Reset Reset	Reset PU Switches	MECOII+1.0	2005.8	2008.7
-	-	Start Tank Pressurization	MECOII+10.0	2014.8	2017.7
-	-	End Pressurization Enable	MECOII+110.0	2114.8	2117.7
69,70	Set	Viking S/C Separation	MECOII+220.0	2224.8	2227.7
8,10 12,14	Set	S2A, S4B, S2B, S4B On	MECOII+825	2829.8	2832.7
8,10 12,14	Reset	S2A, S4B, S2B, S4B Off	MECOII+900	2904.8	2907.7
17,21	Set	C1&C2 Circ Pumps On	MECOII+1050	3054.8	3057.7
19	Set	Open Prestart Valves (Blow Down)	MECOII+1075	3079.8	3087.7
17,21	Reset	C1&C2 Circ Pumps Off	MECOII+1325	3329.8	3332.7
19	Reset	Close Prestart Valves (End Blow Down)	MECOII+1325	3329.8	3332.7
8,10 12,14	Set	S2A, S4A, S2B, S4B On	MECOII+1330	3334.8	3337.7
24,28 31	Reset	Unlock LO_2 Vent Valve Unlock LH_2 Vent Valve 1&2	MECOII+1400	3404.8	3407.7
8,10, 12,14	Reset	S2A, S4A, S2B, S4B Off	MECOII+3330	5334.8	5337.7

(15) MECO 2 - Commanded by the DCU based on guidance computed time.

Propellant Utilization/Propellant Loading System

by K. Semenchuk

Propellant Utilization (PU): The TC-3 propellant utilization system operated satisfactorily throughout the flight. PU valve angle measurements for C1 and C2 engines responded properly. PU valves were properly locked in a null position until 5 seconds after MES-1, when they were properly commanded to the fixed angle positions of 4.2° for C1 and 3.6° for C2 engines. PU valves are to remain in their fixed position for 110 seconds after MES-1, before they are brought into control.

The LO_2 level passed the probe top at MES-1 + 95 seconds, and the LH_2 level passed the probe top at MES-1 + 107 seconds.

DCU enabled the valves to begin controlling at MES-1 + 110 seconds. The valves then moved to the LO_2 rich angle and remained there until 27 seconds before MES-2. At MES-2 + 5 seconds, PU valves went into control again.

The propellant residuals remaining at the Centaur Main Engine Cutoff were calculated by using the times when the propellant levels passed the bottom of the probes as reference points.

Liquid propellant residuals are shown below:

	Actual	Predicted
LO_2	940 lbs.	1,067 lbs.
LH_2	190 lbs.	213 lbs.

The burning time remaining to depletion was calculated to be approximately 16.5 seconds, at which time the liquid propellant outage was determined to be 8 pounds of LH_2.

Propellant Loading Indicating System (PLIS): Centaur Level Indicating System operated satisfactorily during countdown. Propellants tanked at liftoff were 25,485 pounds of LO_2 and 5,285 pounds of LH_2.

Instrumentation and Telemetry Systems

by J. M. Bulloch and T. J. Hill

Instrumentation: For the TC-3 flight a total of 324 measurements were instrumented, 288 PCM measurements and 23 twenty-four bit DCU words via PCM telemetry and 13 FM/FM analog measurements. The following measurements exhibited data anomalies during the flight.

1. CA890P (Spacecraft Compartment Internal Pressure 0 to 15 pia) exhibited intermittent negative transients during vehicle ascent through the atmosphere. These transients are characteristic of wiper liftoff within the potentiometer type transducer.

2. CT70T (Thermocouple Reference Junction Temperature -330° to 108°F) indicated 20°F high (4.6% Information Bandwidth) throughout countdown and flight. This anomaly was known to exist since the Terminal Countdown Demonstration (TCD) and was considered acceptable. The cause of this anomaly is unknown.

3. CP833T (LH_2 Boost Pump Inlet Line Temperature -50 to +147°F) exhibited temperature variations indicative of local environment rather than H_2O_2 line temperature. The most probable cause is considered to be excessive adhesive under the resistance patch or delamination of the patch from the line.

4. CP691T (S2A Chamber Surface Temperature -275°F + 1625°F) drifted -10% IBW within 10 seconds at T + 4057 seconds. A second +2% IBW tep was noted at T + 5471 seconds. The measurement appeared to be satisfactorily tracking temperature changes with the exception of these steps. The cause of this anomaly is unknown.

5. CP118T (C-1 Engine Fuel Pump Backup Temperature -430°F to -57°F), CP119T (C-2 Engine Fuel Pump Backup Temperature -430°F to -57°F), CP122T (C-1 Engine Fuel Pump Temperature -425°F to -124°F), CP123T (C-2 Engine Fuel Pump Temperature -425°F to -124°F), CP124T (C-1 Engine LO_2 Pump Temperature -310°F to +104°F), and CP125T (C-2 Engine LO_2 Pump Temperature -310°F to +104°F). All exhibited slow response during the flight. This condition may arise because of the Pratt and Whitney transducer installation. The slow response problem has occurred on previous flights.

Telemetry: The telemetry R.F. systems on TC-3 operated satisfactorily. The Centaur PCM system provided 288 measurements on the 2202.5 MHz R.F. link, and the FM/FM system provided 13 analog measurements on the 2208.5 MHz link. Ground station coverage intervals for these two links are shown in Figures 8-8.1, 8-8.2 and 8-8.3.

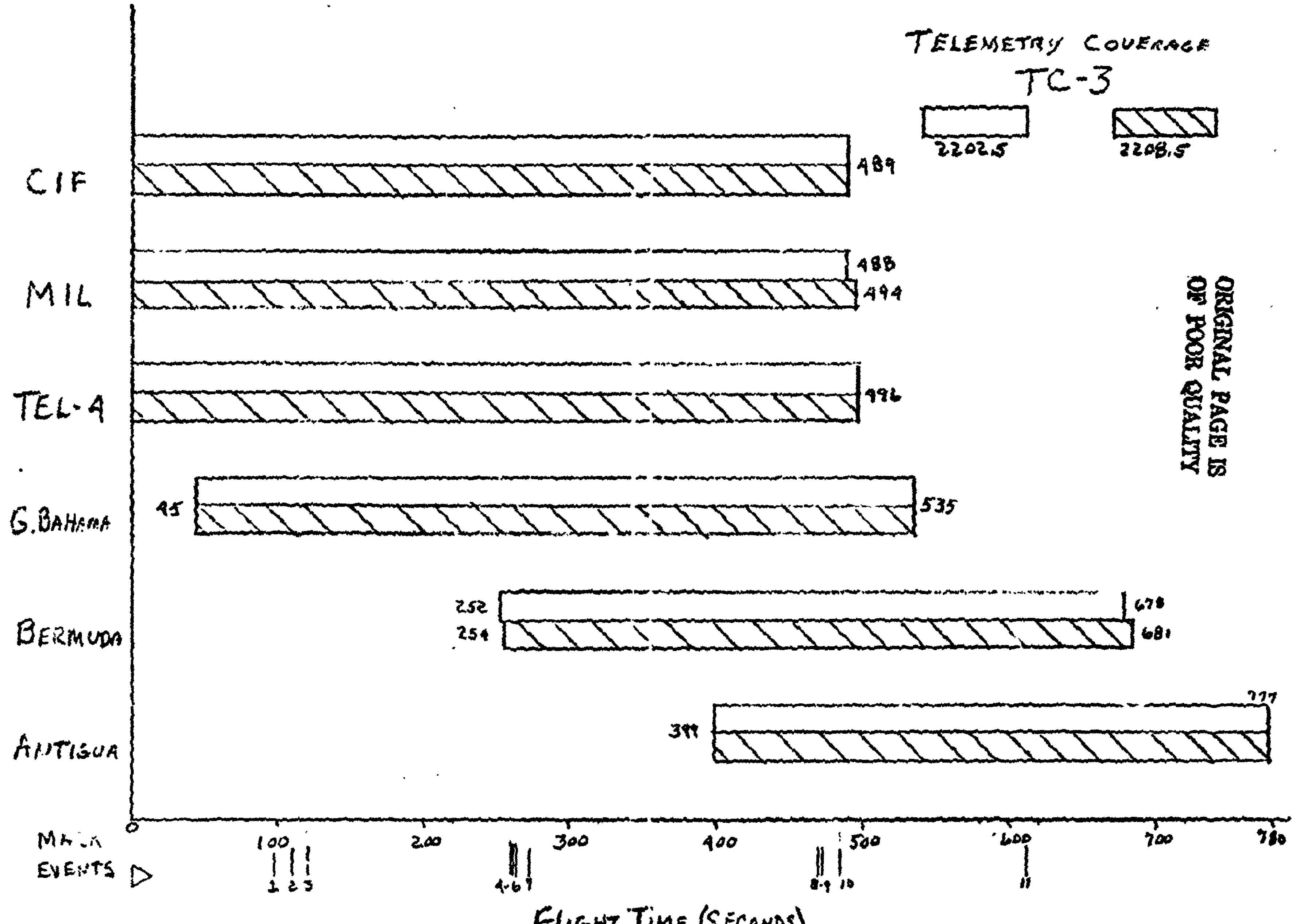

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FIGURE 8-8.1 - TC-3 TELEMETRY COVERAGE

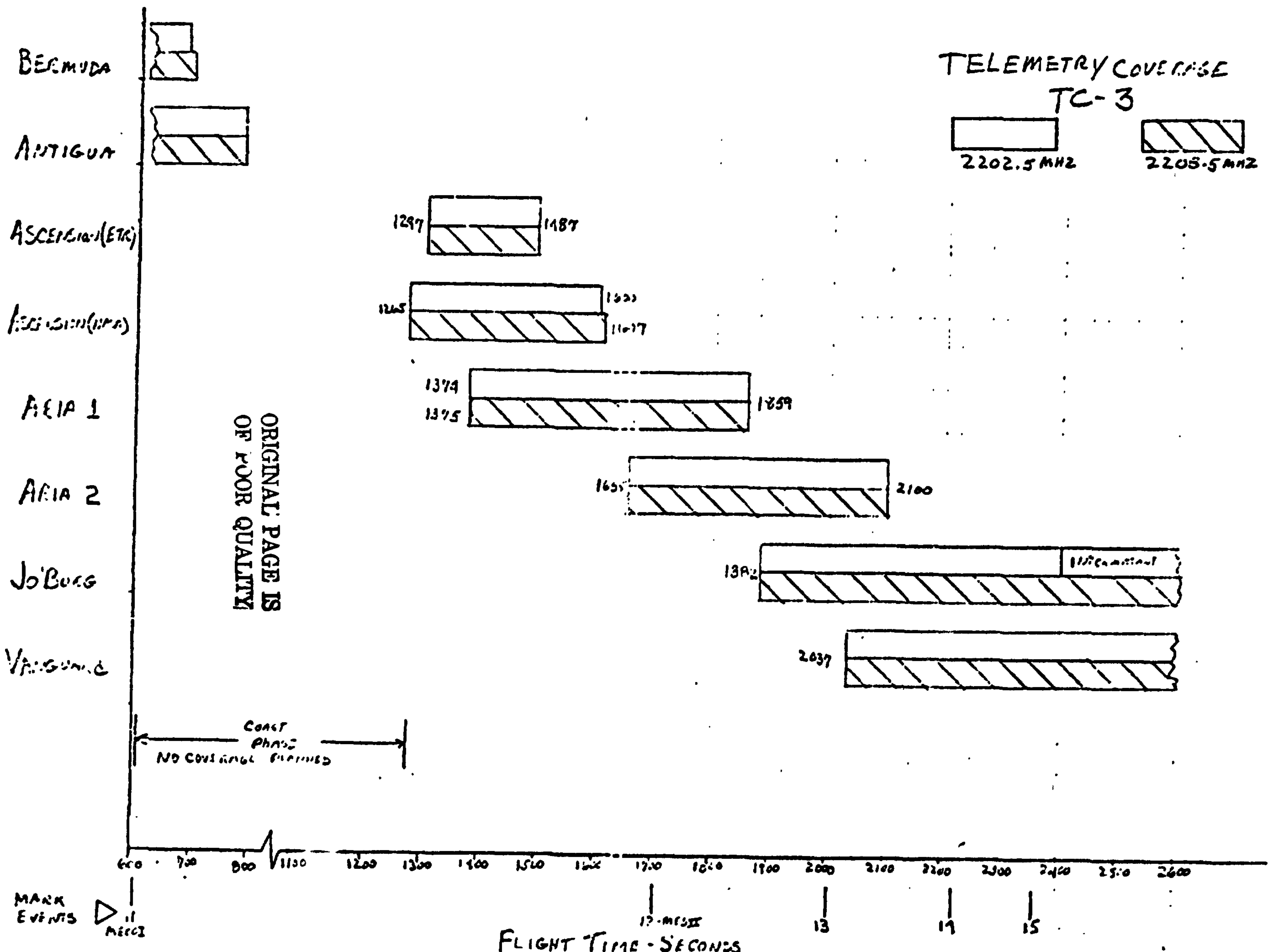

FIGURE 8-8.2 - TC-3 TELEMETRY COVERAGE

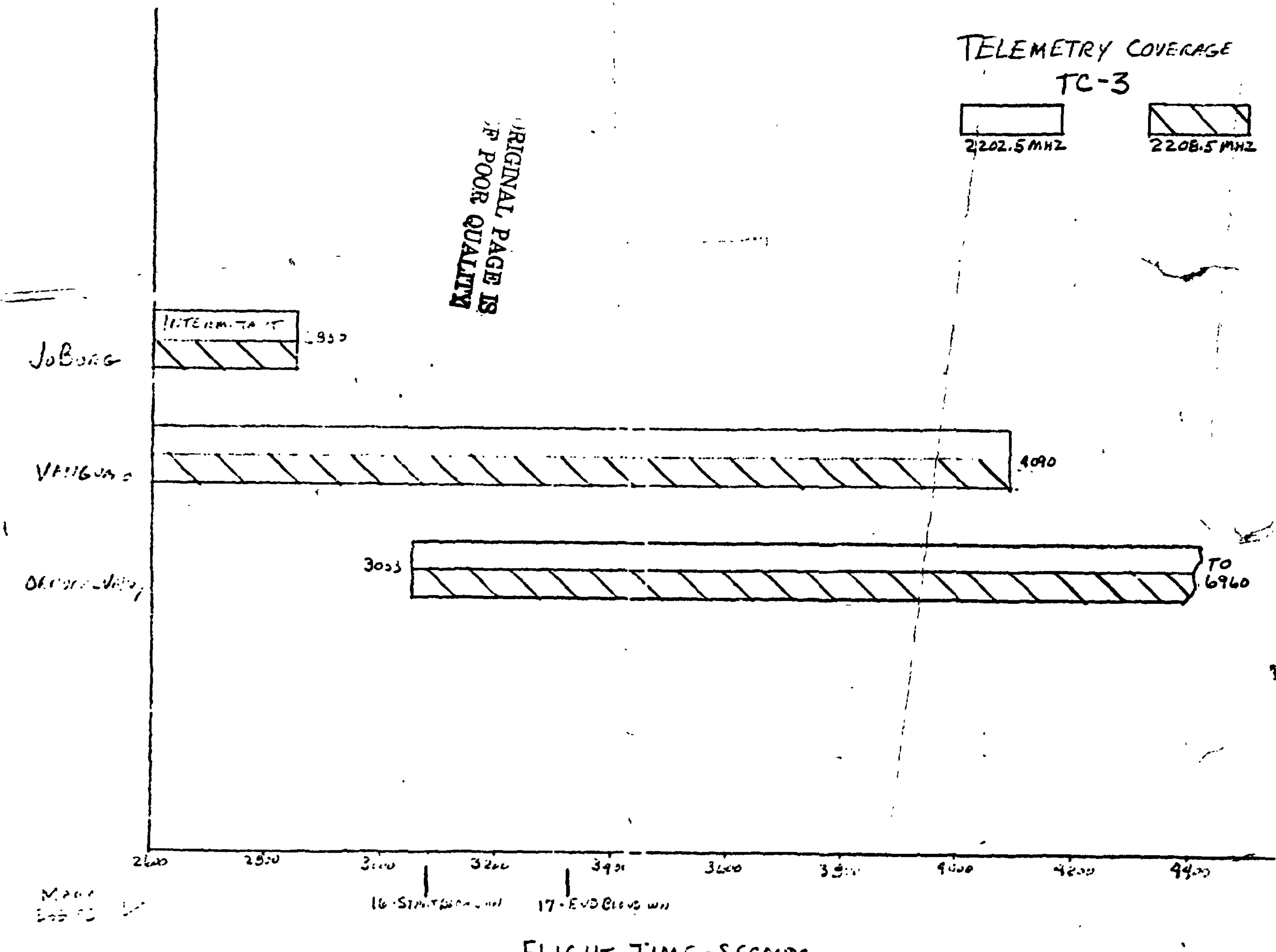

FIGURE 8-8.3 - TC-3 TELEMETRY COVERAGE

Signal strengths reported by the participating telemetry stations indicated satisfactory performance of the airborne R.F. systems. Johannesburg reported intermittent PCM lock for the last 450 seconds on the 2202.5 MHz link, but solid PCM data for this interval was provided by the U.S.N.S. Vanguard.

The ARIA 3 aircraft was scheduled to support this mission but did not deploy because of an aircraft problem.

Tracking and Range Safety Systems

by T. J. Hill and J. M. Bulloch

C-Band Tracking: The C-band tracking system on TC-3 operated satisfactorily. The ground radar tracking intervals are shown in Figure 8-9. No significant tracking problems attributable to the Airborne System were reported by the tracking radar stations.

Radar Station 12.16 (Ascension) reported multipath dropouts at 1405 seconds for 20 seconds and again at 1488 seconds for 14 seconds. Radar 12.15 covered these intervals with no problems.

Range Safety Command System: Operation of the Range Safety Command System was satisfactory. Signal (AGC) data indicated a satisfactory received signal level throughout the flight. System control was maintained as the vehicle flew downrange by switching of TSC transmitter control stations. Switching times are presented in the following table.

Station	Carrier On (Sec)	Carrier Off (Sec)
Cape Canaveral	-2309	172
Grand Bahama Island	170	461
Antigua	461	647

The Antigua transmitter sent Range Safety Command RF disable at T + 624 seconds resulting in shutdown of the airborne RSC receivers.

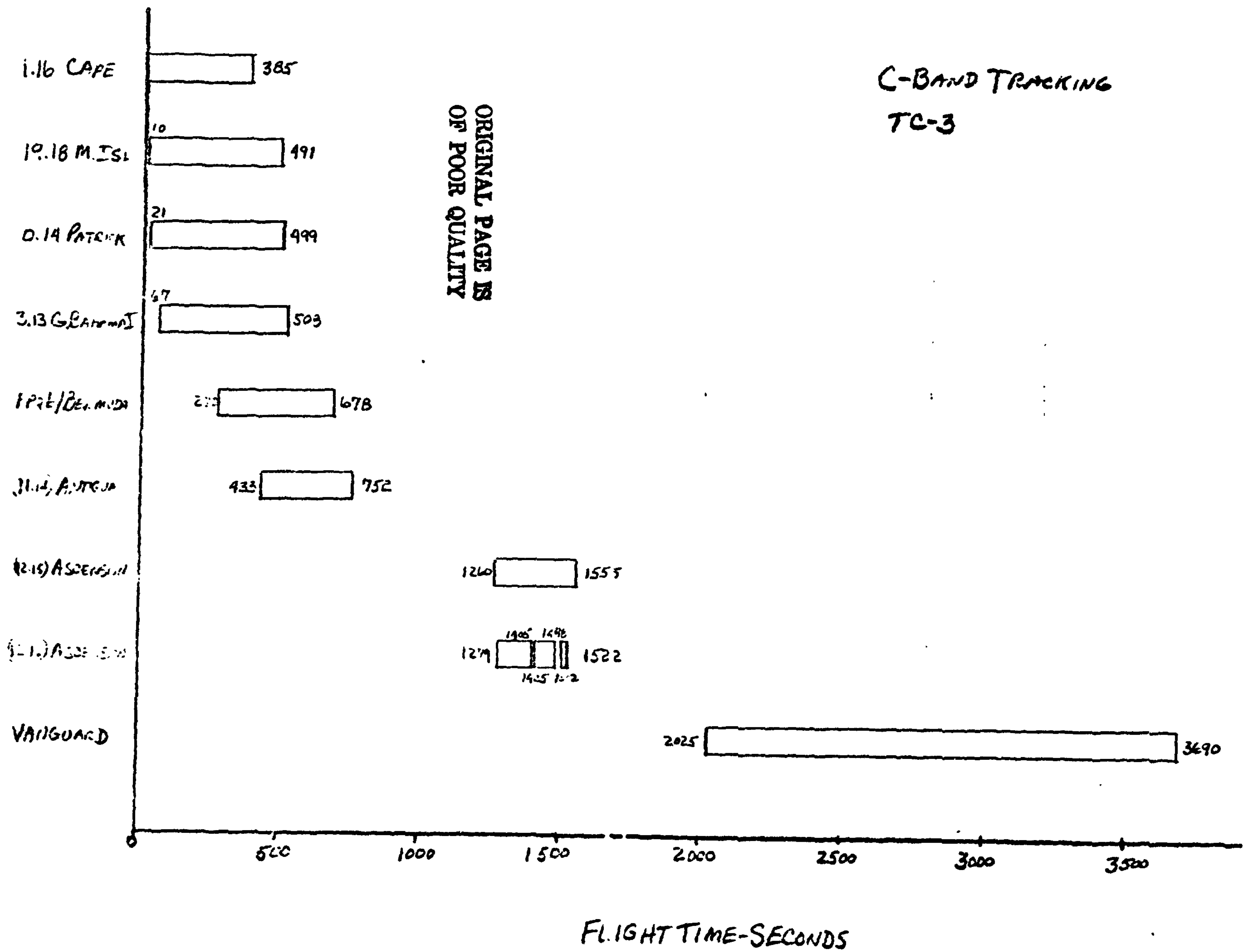

FIGURE 8-9 - TC-3 C-BAND TRACKING

IX CENTAUR STANDARD SHROUD (CSS)

IX CENTAUR STANDARD SHROUD (CSS)

Liftoff/In-flight Functions

by T. L. Seeholzer

CSS Disconnects and Door Closures: The CSS disconnects and door closures located as shown in Figure 9-1 functioned normally on the TC-3 flight. The CSS disconnects and door closures were equivalent to the systems used on the TC-2 flight with the exception of the encapsulation seal and RTG doors which were Viking peculiar and incorporated on the TC-1 flight.

Movie and television coverage verified proper disconnect of the umbilicals and the closing of the T-0 and T-4 CSS doors on the primary latches.

Microswitches mounted on the T-4 aft door verified that the door closed on the primary latches following umbilical disconnect. However, during the door closing, an intermittent signal was indicated by CMV60X. The intermittency was caused by one or both microswitches which are wired in parallel and occurred between T-2.32 and T-2.23 seconds. At T-1 seconds, the door switches indicated closed maintaining the automatic sequence.

CSS In-flight Events and Jettison: All CSS in-flight events and jettison were normal on the TC-3 flight. These events included forward bearing reaction separation, forward seal release, shroud separation and jettison as shown in Figures 9-2 through 9-6. These systems were equivalent to those on the TC-1 and TC-2 flights.

Discussion

All six forward bearing reaction struts were separated at T + 100.07 seconds as verified by breakwires on the explosive bolts. Nominal separation time was T + 100 seconds.

Forward seal release occurred at T + 211.07 seconds as verified by breakwires on the explosive bolts. Nominal separation time was T + 210 seconds.

The CSS Super*Zip primary system separated the shroud at T + 271.67 seconds. Separation by the primary system was verified by the fact that the CSS rotated over 3° prior to secondary system command. The secondary command was issued .50 seconds after primary system command. The secondary system is deactivated by electrical disconnect after 1° rotation.

Shroud rotation times comparing TC-1, TC-2, TC-3 and TC-4 are given in Table 9-1.

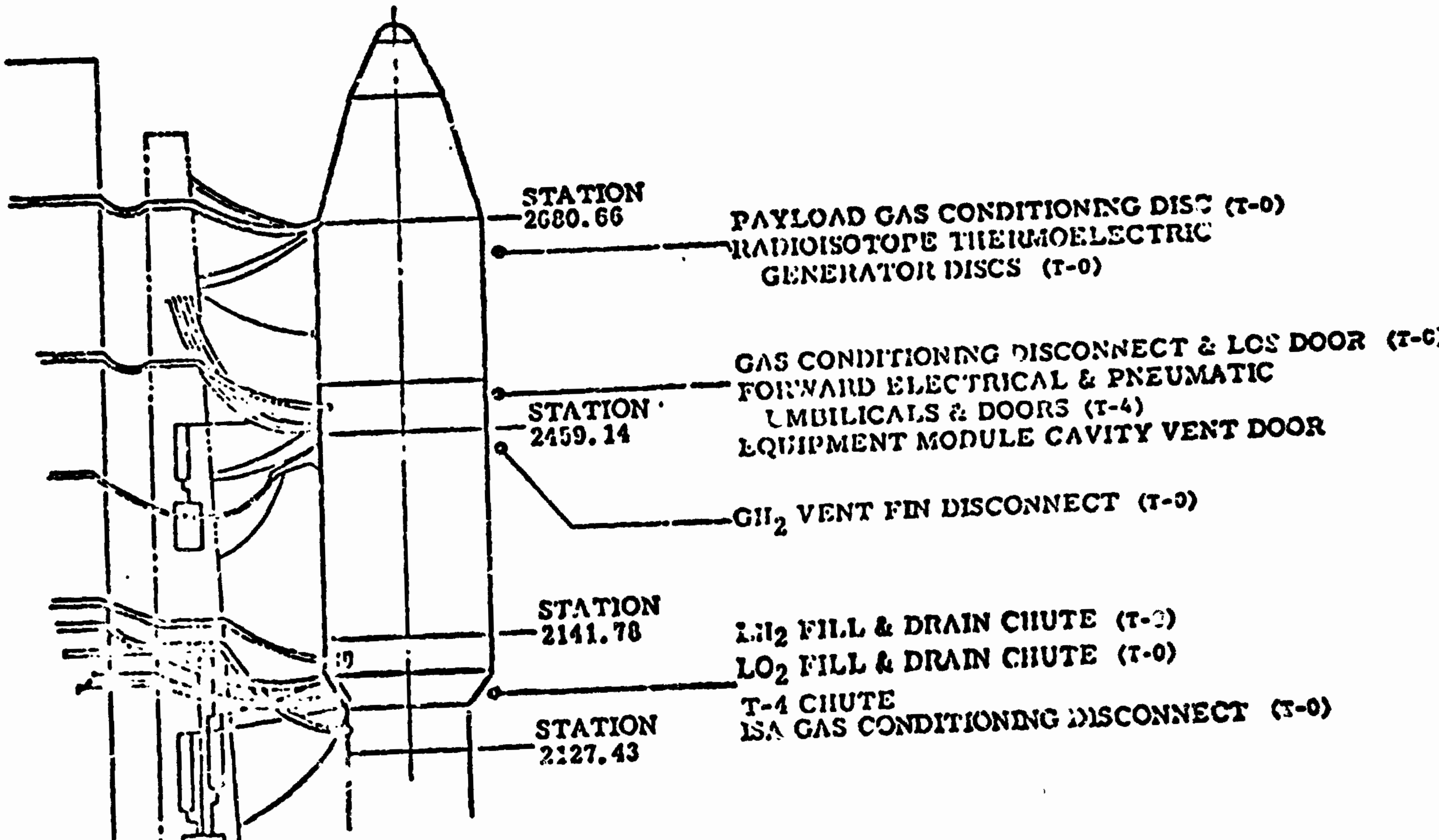

FIGURE 9-1 - CENTAUR STANDARD SHROUD DISCONNECTS AND DOOR CLOSURES

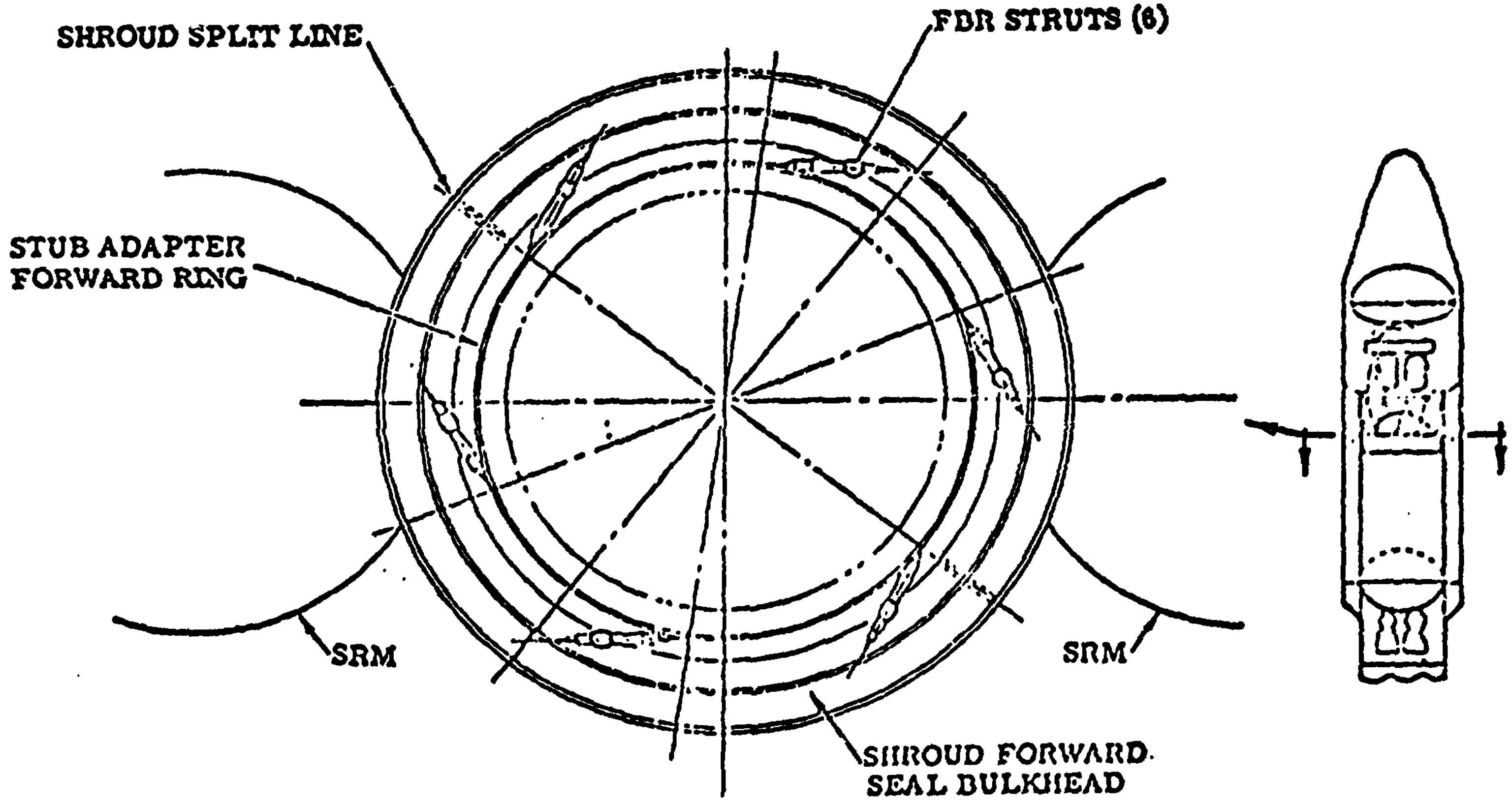

FIGURE 9-2 - FORWARD BEARING REACTION SYSTEM

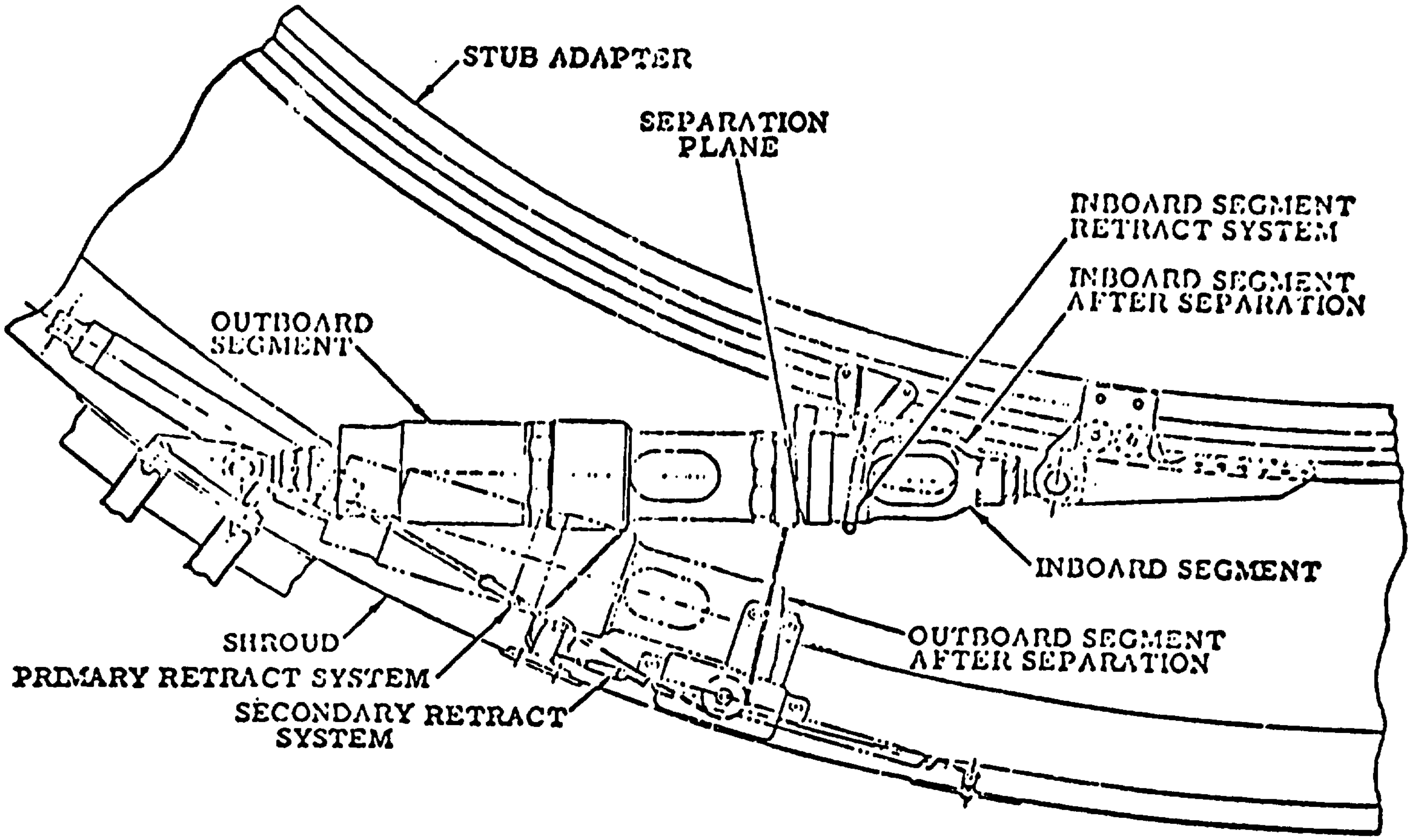

FIGURE 9-3 - FORWARD BEARING REACTION STRUT INSTALLATION

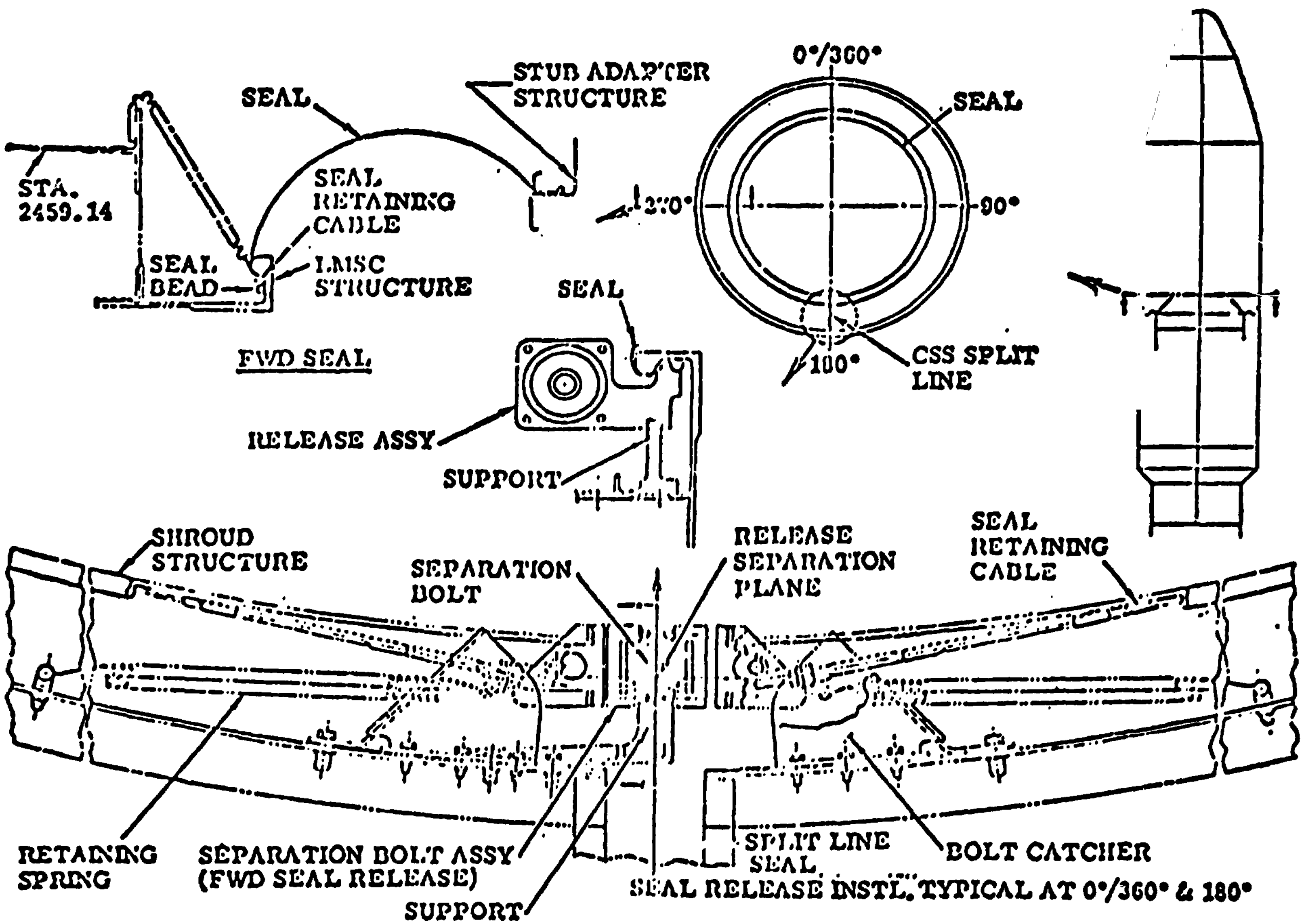

FIGURE 9-4 - FORWARD SEAL

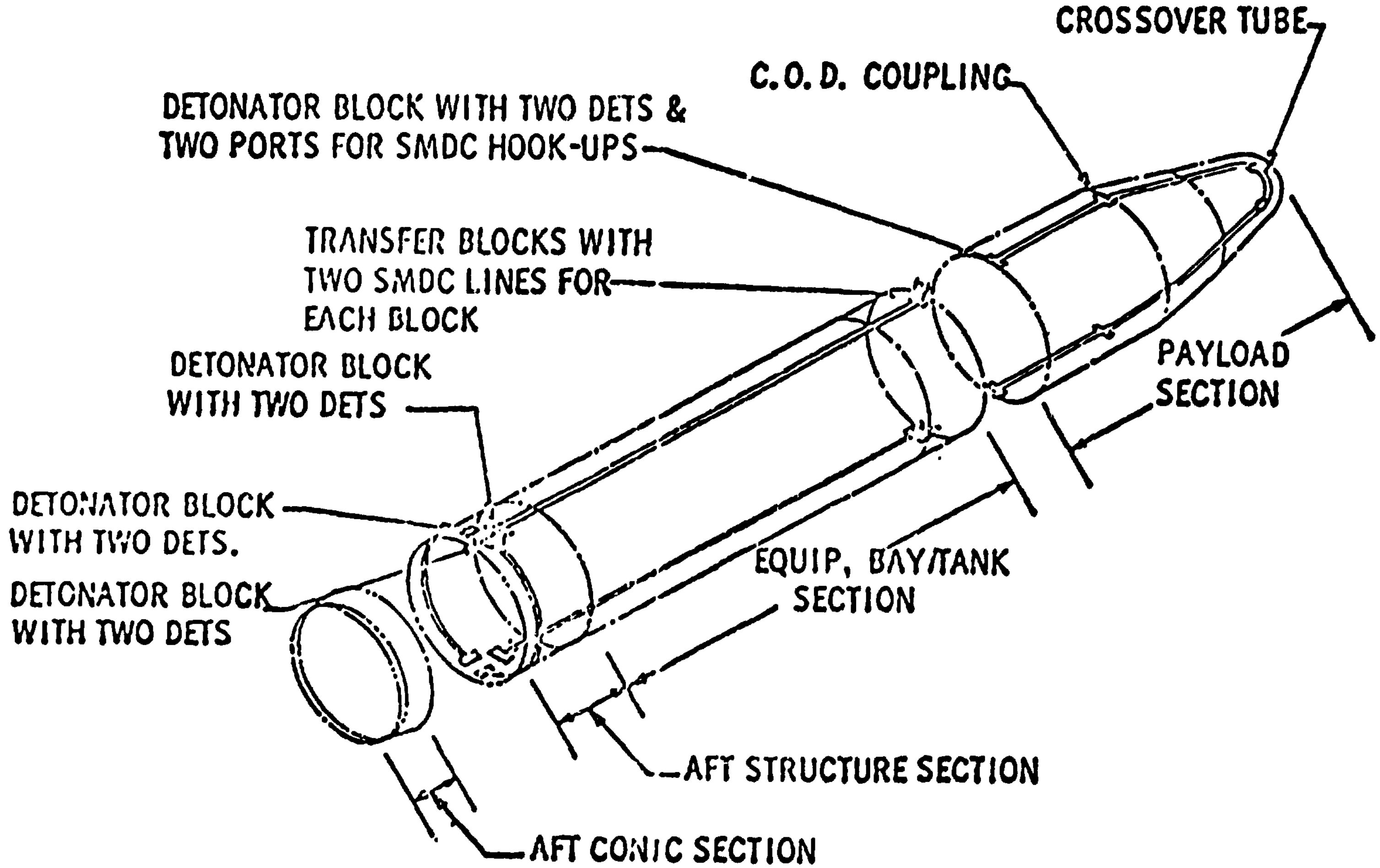

FIGURE 9-5 - SUPER * ZIP SEPARATION SYSTEM

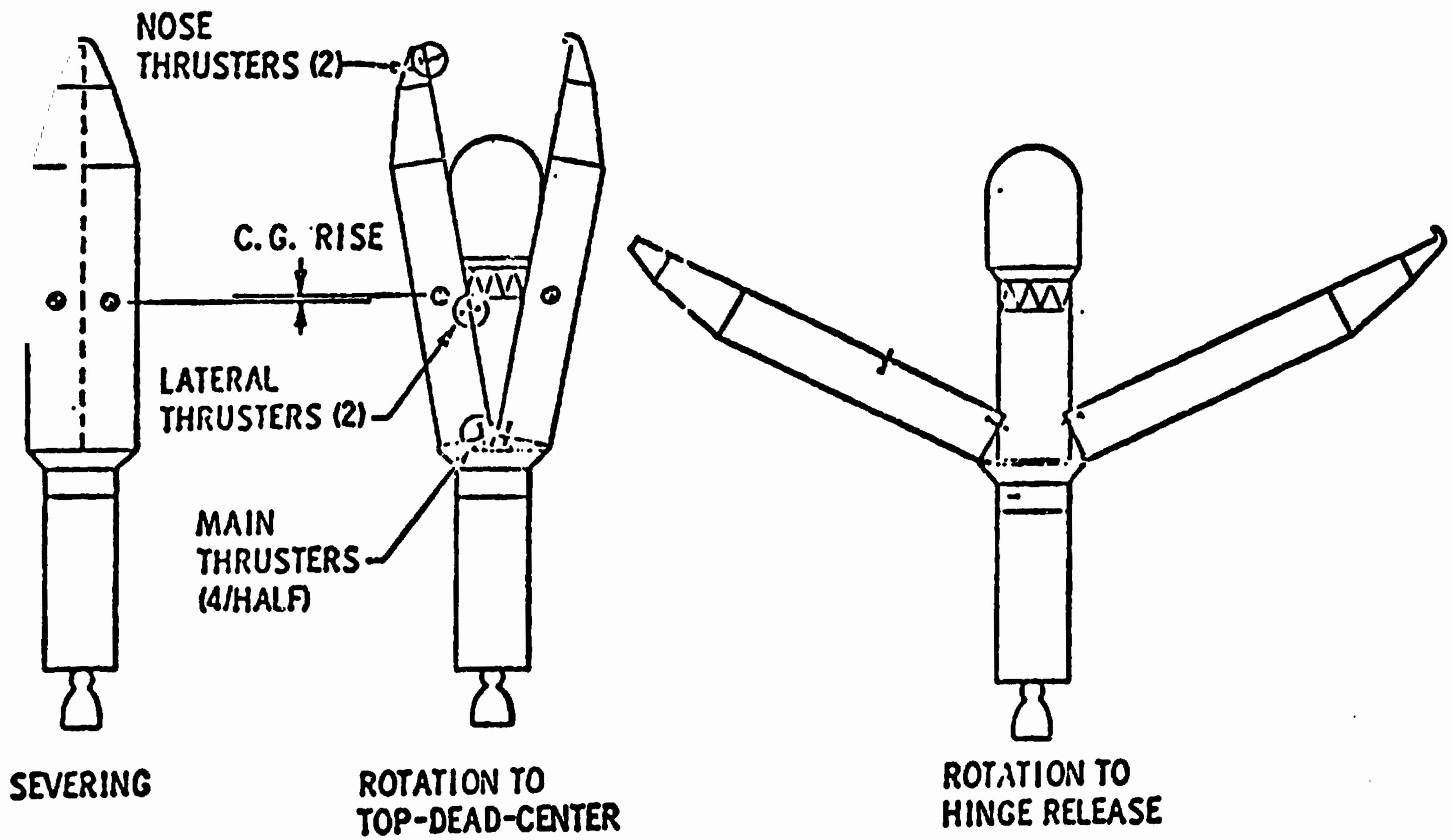

FIGURE 9-6 - JETTISON SEQUENCE AND SPRING LOCATION

TABLE 9-1 - CSS BREAKWIRE SUMMARY

BREAKWIRE (ROTATION AND LOCATION)		TIME FROM PRIMARY COMMAND (SECONDS)			
		TC-1	TC-2	TC-3	TC-4
3^0 QUAD I	CAPPED	.40	.39	.39	.36
3^0 QUAD II	CAPPED	.42	.41	.41	.36
3^0 QUAD III	UNCAPPED	.39	.41	.39	.36
3^0 QUAD IV	UNCAPPED	.40	.40	.39	.36
8^0 QUAD I - II	CAPPED	.65	.76	.71	.69
8^0 QUAD III - IV	UNCAPPED	.72	.76	.69	.70
32^0 QUAD I - II	CAPPED	2.02	1.86	1.86	1.89
32^0 QUAD III - IV	UNCAPPED	1.84	1.56	1.77	1.75

CSS Ascent Vent System

by W. K. Tabata

Summary

The CSS Ascent Vent System performed satisfactorily in-flight. The reduction in spacecraft compartment maximum dp/dt during transonic expected by blocking two of th 11 vents was realized.

Discussion

Spacecraft Compartment: Time-pressure history of the spacecraft compartment is shown in Figure 9-7. The data agree well with TC-1 and TC-2. Blocking two of the 11 vents affected the compartment internal absolute pressure only insignificantly as predicted by preflight analysis. The maximum dp/dt during transonic was -0.65 psi/sec. (Figure 9-8). The spacecraft bioshield experienced a maximum ΔP of 0.35 psi as predicted in the normal spacecraft venting case.

Titan 2A Compartment: Venting of the Titan 2A compartment was normal. Pressure-time history of the 2A compartment is shown in Figure 9-9 compared to TC-1 and TC-2.

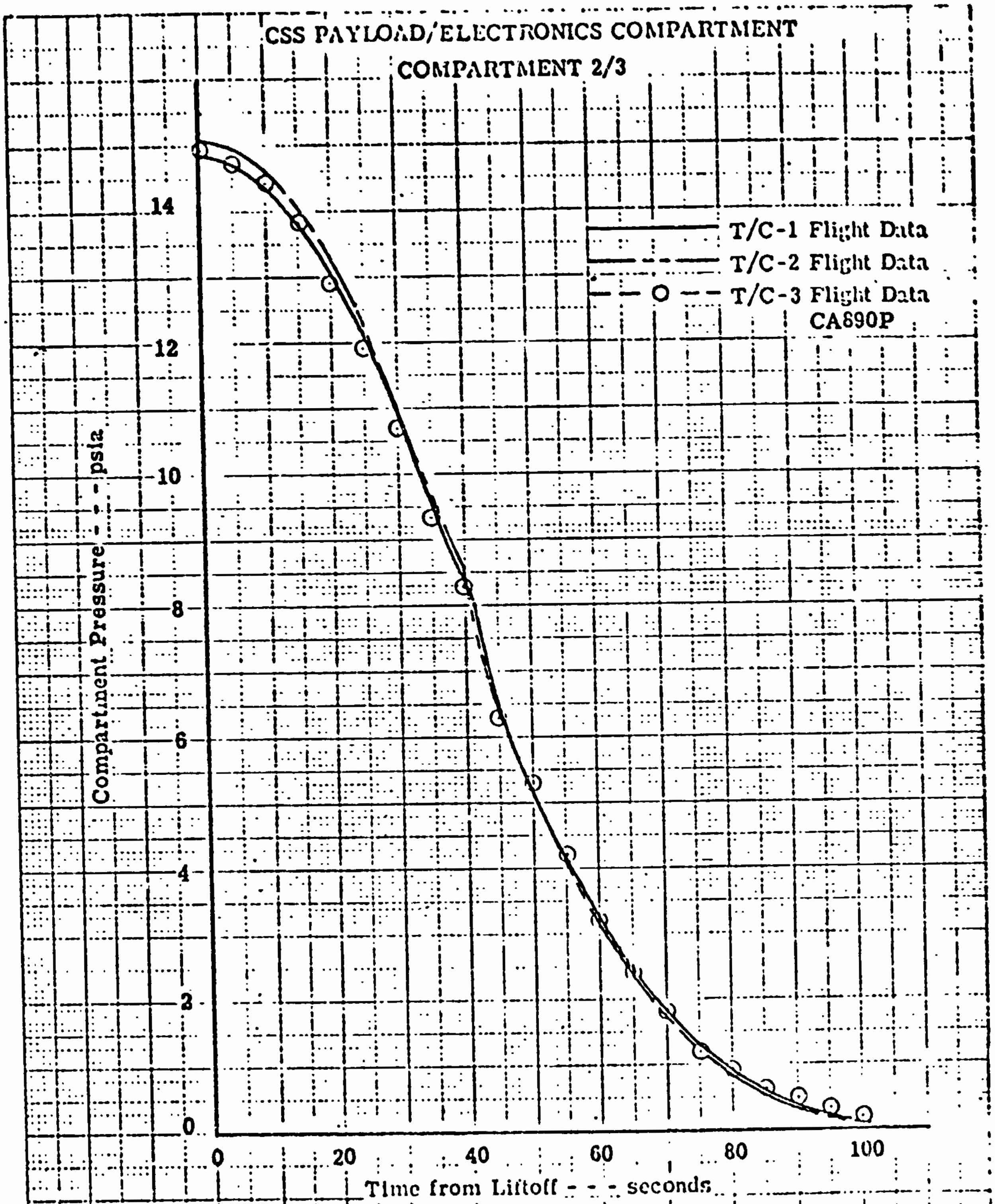

Figure 9-7 -CSS Payload/Electronics Compartment Pressure History

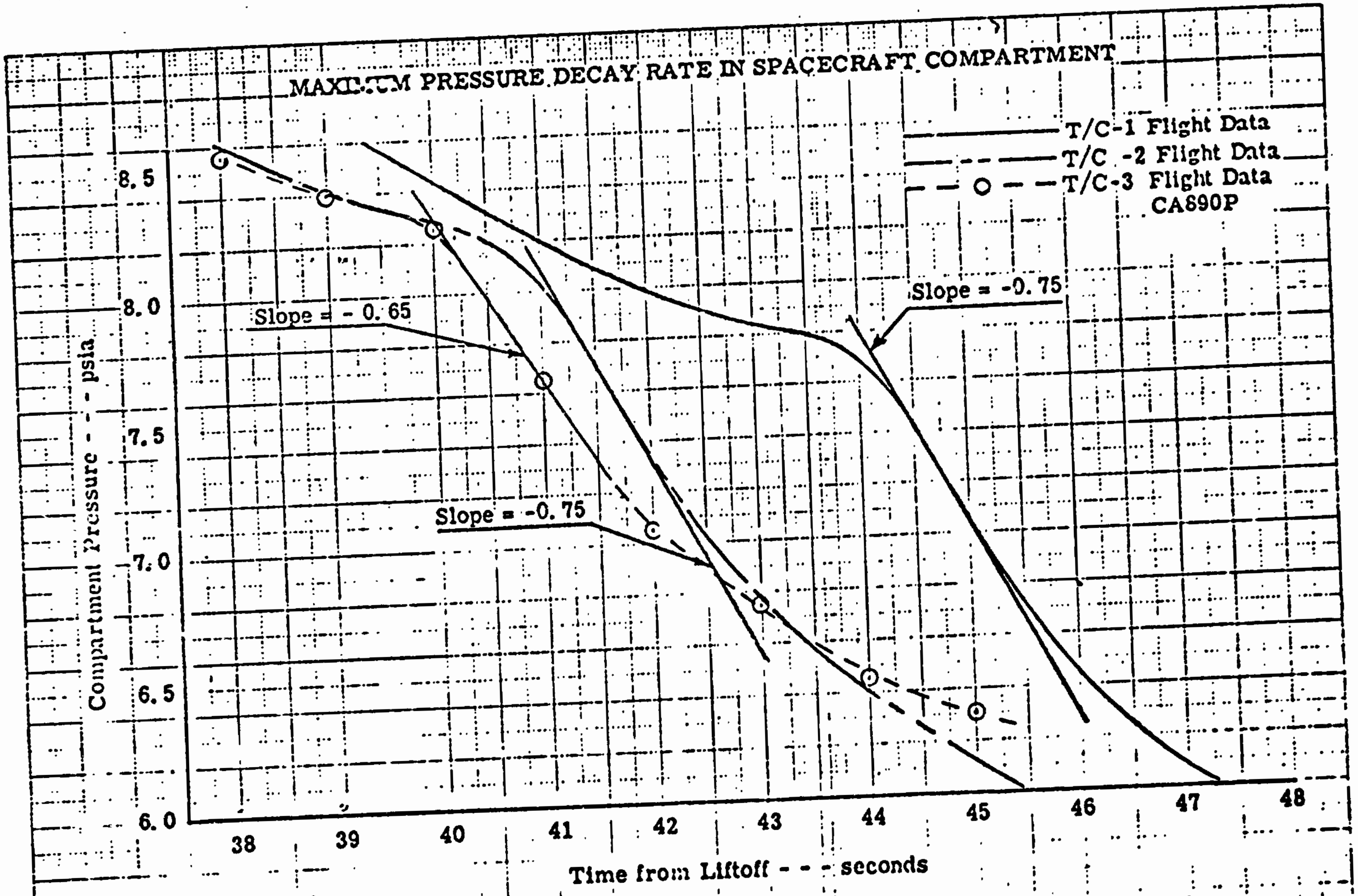

Figure 9-8-Maximum Pressure Decay Rate in Spacecraft Compartment During Transonic

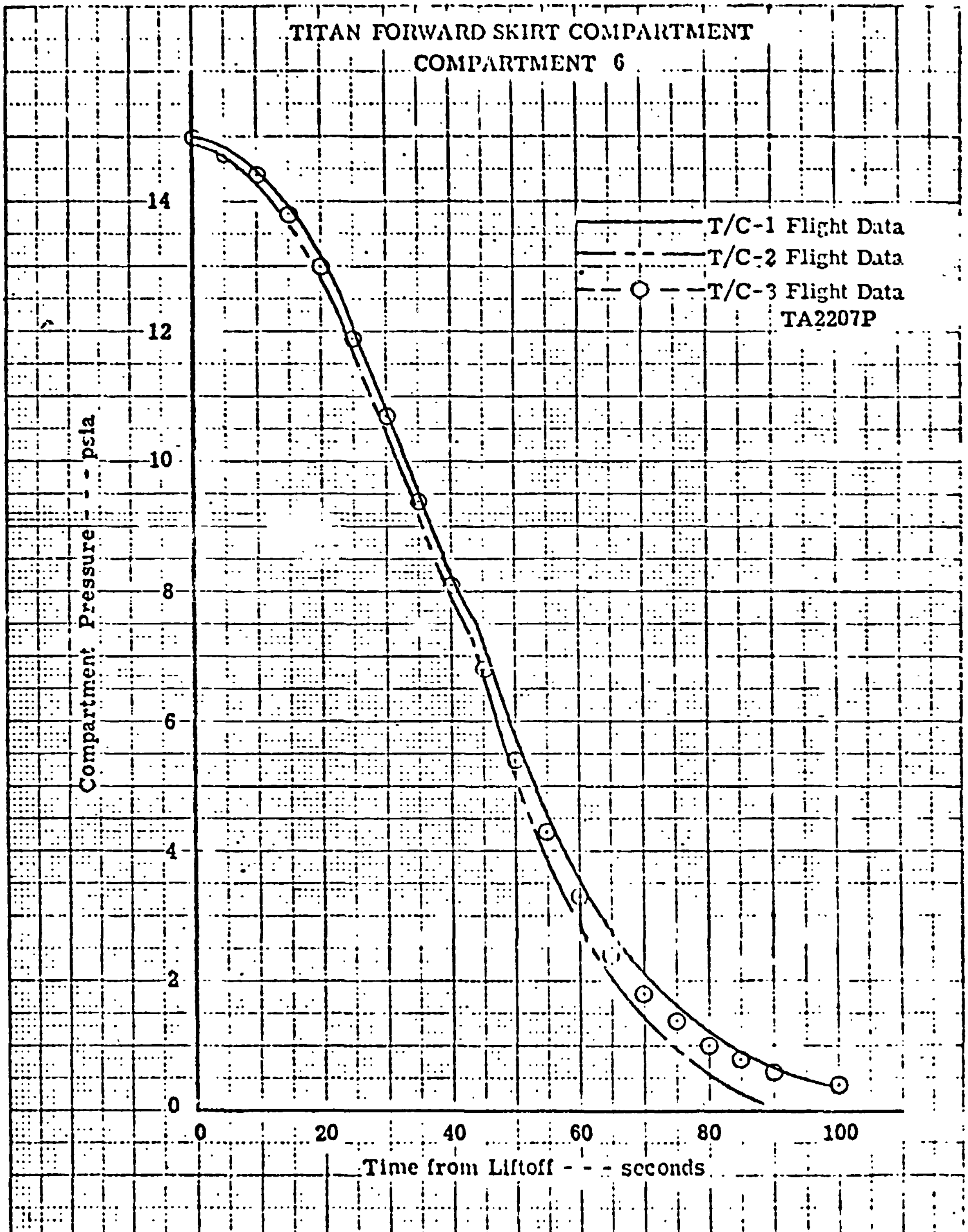

Figure 9-9 - Titan Forward Skirt Compartment Pressure History

X TITAN/CENTAUR GROUND SYSTEMS

X TITAN/CENTAUR GROUND SYSTEMS

by H. E. Timmons and A. C. Hahn

The countdown for the launch of TC-3 began at 3:04 a.m. on September 9, 1975, at T-625 minutes. During the entire countdown, the ground systems functioned normally with the following reported anomalies.

At approximately T-250 minutes, it was noted that the Data Recording and Quick Look Set (DRQLS) in the VIB ground station had not been printing for some time. Investigation showed that the printer portion of the system had shut down even though the data recording portion of the system was operating properly. The printer power was cycled off and back on. This action placed the printer back in operation. Playback of the data from magnetic tape showed that the printer had been off line since approximately T-370 minutes, a period of about 2 hours. All data was retrieved from the tape successfully and there was no interruption of the countdown. Post-launch troubleshooting found that the problem was associated with overheating of the printer electronics. The overheating was caused by a cover which had been put on the printer for noise suppression just prior to the Viking activity.

At T-2.27 seconds the signal from the Centaur aft door pulsed. This signal indicates that the door is closed properly and is one of a series of signals which make up the Aft Plate Ejected Signal in the launch ladder. The pulses lasted approximately 0.09 seconds, with a solid signal going to the CMG at T-2.187. This signal must be sent by T-1.0 seconds or the countdown is aborted. Cause of the pulsing was an apparent malfunction of the microswitches or the wiring to the microswitches on the door latch mechanism. From films, it appeared that, once the door latched the signal came on properly and solidly. Some modifications to the door closing forces and the latch spring mechanism as well as the switches themselves are being investigated as potential future preventative measures.

During the launch sequence the el ctrical umbilical disconnect times were as shown in Table 10-1. The umbilical release sequence on the Titan umbilicals was not as predicted. The 2A1E umbilical preceded 1C1E in the disconnection sequence. This was the same sequence encountered on TC-2. No action will be taken to correct the umbilical sequence since no adverse effects have been identified as a result of previous flight sequences, tests or from analysis.

At umbilical disconnect three DRS channels pulsed: Channel 008 - Stage 1 Shu down Enable Backup Simulation Signal; Channel 046 - Stage 2 Destruct Initiator Armed Indication; Channel 101 - Stage 2 Engine Shutdown Monitor.

TABLE 10-1 - TC-3 ELECTRICAL UMBILICAL DATA

CMG T-0 (DRS Channel 295 off) = 1838:59.917
Ignite SRM Command (DRS 739) = 1838:59.938
SRM Ignition Relay Closed (DRS 496) = 1838:59.956 (Official T-0)

Titan Umbilicals	Time Disconnected	Time from Official T-0
LB1E	1839:00.313	T + 0.357
RB1E	1839:00.316	T + 0.360
2A1E	1839:00.364	T + 0.408
1C1E	1839:00.373	T + 0.417
2A2E	1839:00.397	T + 0.441
2C1E	1839:00.466	T + 0.510
Centaur Umbilicals		
B600P3	1838:56.750	T - 3.216
B600P2	1838:56.983	T - 2.773
B600P1	1838:57.241	T - 2.515
B600P4	1839:00.613	T + 0.657
B600P5	1839:00.727	T + 0.771

Random pulsing of channels at liftoff has been noted on all flights, both Titan/Centaur and Titan IIIC, since the DRQLS was installed. The time resolution on pulses with DRQLS is 3.33 milliseconds as opposed to 10 milliseconds on the DRS previously installed in the VIB. This indicates that these pulses were apparently present all along but were too fast to get recorded previously. There is no apparent adverse affect due to this pulsing. A suspected cause of the pulsing is the loss of ground for the length of time it takes a contractor to transfer the power supplies to facility ground once the vehicle single point ground connection is broken at liftoff.

During the launch sequence the Centaur mechanical umbilical disconnect times were as shown in Table 10-2.

The indication on DRS of the Centaur LH_2 fill and drain valve disconnection was extremely late. This indication came 1.434 seconds after the command from the CMG to disconnect the valve. Nominal time of valve disconnection is 0.5 to 0.6 seconds. Review of analog data on the retract cylinders indicates that actual operation was nominal with a disconnect time of approximately 0.56 seconds. This anomaly was the same one encountered on TC-4. It was suspected after the TC-4 launch that the controller for the transducer which provides the DRS signal was faulty. The controller was replaced for TC-5.

A fire broke out in the AGE Building in the southeast corner near the MTR after launch. It was discovered by the post-launch safing crew upon their return to the pad. The fire caused significant damage within the AGE Building and was the subject of exhaustive investigations. The results of these investigations and the resulting modifications are the subject of other reports and are not included within the scope of this report.

TABLE 10-2 - TC-3 MECHANICAL UMBILICAL DATA

Centaur

Event	Time	Time from CMG T-0
Aft Plate Eject Commanded	1838:55.939	T - 3.978
Aft Door Closed	1838:57.727	T - 2.190
Aft Plate Ejected	1838:57.730	T - 2.187*
LH_2 Fill & Drain Valve Eject Command	1838:59.455	T - 0.459
LO_2 Fill & Drain Valve Eject Command	1838:59.455	T - 0.459
LO_2 Fill & Drain Valve Disconnected	1838:59.845	T - 0.072
LH_2 Fill & Drain Valve Disconnected	1838:00.02**	T + 0.10**

* Time shown for Aft Plate Ejected is time when signal came on permanently after an initial anomalous indication.

** Disconnect time for LH_2 Fill & Drain Valve established from analog data on retract cylinder. Signal to DRS from the valve indicator control assembly indicated a total disconnect time of 1.413 seconds. Post-launch analysis verified that the DRS time anomaly was the result of a malfunctioning control assembly.